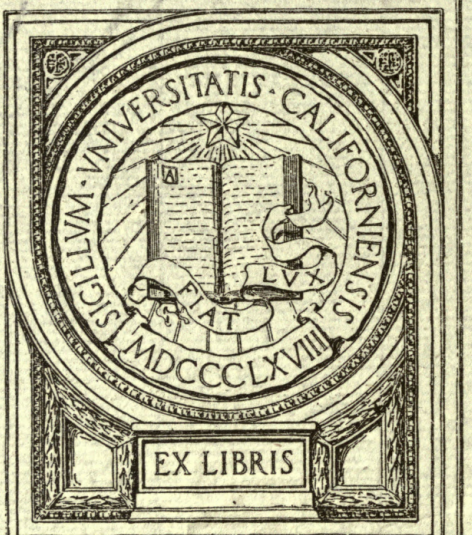
THE NATVRAL HISTORY OF ANIMALS



BIOLOGY
LIBRARY
G

The Natural History of Animals

THE CORAL SNAKE (ELAPS CORALLINUS)

The Natural History of Animals

The Animal Life of the World in its various Aspects and Relations

BY

J. R. AINSWORTH DAVIS, M.A.

TRINITY COLLEGE, CAMBRIDGE
PROFESSOR IN THE UNIVERSITY OF WALES, AND PROFESSOR OF ZOOLOGY AND GEOLOGY IN UNIVERSITY COLLEGE, ABERYSTWYTH

HALF-VOL. IV

UNIV. OF CALIFORNIA

LONDON
THE GRESHAM PUBLISHING COMPANY
34 SOUTHAMPTON STREET, STRAND
1903

QL43
D3
v.4
BIOLOGY
LIBRARY
G

UNIV. OF
CALIFORNIA

CONTENTS

HALF-VOL. IV

THE FOOD OF ANIMALS (*Continued*)

CHAPTER XXIII.—THE FOOD OF ANIMALS—OMNIVOROUS ANNELIDS, SIPHON-WORMS, LAMP-SHELLS, MOSS-POLYPES, AND WHEEL-ANIMALCULES

Page

BRISTLE-WORMS (Chætopoda)—Lob-Worm, Tube-Worms (Serpula, Pomatoceros, Spirorbis), Earth-Worms - - - - - - - - - - - - - 257

SIPHON-WORMS (Gephyrea)—Common Siphon-Worm - - - - - - - 259

LAMP-SHELLS (Brachiopoda) - - - - - - - - - - - - - - 260

MOSS-POLYPES (Polyzoa) - - - - - - - - - - - - - - 261

WHEEL-ANIMALCULES (Rotifera)—Rose-coloured Rotifer, Crown Rotifer, Flower Rotifer - - - - - - - - - - - - - - - - 261

CHAPTER XXIV.—THE FOOD OF ANIMALS—OMNIVOROUS ECHINODERMS, SPONGES, AND ANIMALCULES—ANIMALS WHICH FEED LIKE GREEN PLANTS

HEDGEHOG-SKINNED ANIMALS OR ECHINODERMS (Echinodermata): Sea-Urchins (Echinoidea); Sea-Cucumbers or Holothurians (Holothuroidea); Crinoids (Crinoidea)—Feather-Stars and Sea-Lilies - - - - - - - 264

SPONGES (Porifera) - - - - - - - - - - - - - - - 265

ANIMALCULES (Protozoa): Infusoria—Ciliata (Slipper Animalcule, Bell Animalcule); Flagellata (Euglena, Collar Animalcules, Monads); Rhizopoda—Proteus Animalcule or Amœba, Foraminifera, Fungus-Animals (Mycetozoa) - - - 266

ANIMALS WHICH FEED LIKE GREEN PLANTS—Animals, Green Plants, and Colourless Plants (Fungi, &c.) compared as regards Food and Feeding: Leaf-Green or Chlorophyll—Animals which contain Chlorophyll—Green Planarian Worm (Convoluta); Green Freshwater Polype, Coral-Polypes; Freshwater Sponge; Green Animalcules (Berry Animalcule, Volvox) - - - - - 270

ANIMAL DEFENCES

CHAPTER XXV. — ANIMAL DEFENCES — INTRODUCTORY — BODILY CHARACTERISTICS PRODUCING INCONSPICUOUSNESS

Page

INTRODUCTORY—Different Kinds of Defence against Predaceous Forms.—I. PRECAUTIONARY MEASURES:—(1) BODILY CHARACTERISTICS resulting in (*a*) Inconspicuousness, (*b*) Conspicuousness: (2) MODE OF LIFE—(*a*) Feeding at Favourable Times, and (*b*) Feeding in Favourable Places.—II. RESISTANCE:—(*A*) PASSIVE DEFENCE by:—(1) BODILY CHARACTERISTICS such as (*a*) Unpalatableness and Indigestibility, (*b*) Armour: (2) SPECIAL HABITS, *e.g.* Death-feigning: (3) FECUNDITY:—(*B*) ACTIVE DEFENCE by means of (1) Ordinary AGGRESSIVE WEAPONS, (2) Actively DEFENSIVE WEAPONS, (3) CO-OPERATION:—III. RETREAT - - - - - - - - - - - - - 275

INCONSPICUOUSNESS:—General Protective Resemblance; Transparency; Marine Surface Animals; Snow Animals—Snowy Owl; Desert Animals—Camels, Antelopes, Desert Foxes, Jerboas, Desert Larks, Desert Finches, Sand-Grouse, Sand-Lizard, Thorn-tailed Lizards, Desert Monitor, Common Skink, Adder, Horned Viper, Desert Insects; Reversed Shading; Flat Fishes - - - 277

Specialized General Resemblance—Corals and Sea-Snails, Corals and Brittle-Stars, Sponges and Sea-Slugs - - - - - - - - - - - - - 285

Protective General Resemblance in Eggs and Young—Plovers, Moths, Beetles - 285

Masking—Land-Snails, Sea-Snails, Crabs, Sea-Urchins, Sea-Anemones - - - 287

Variable General Resemblance: Colour-Change in Snow-Animals—Variable Hare, American Hare, Stoat, Weasel, Ptarmigan; Colour-Change in Chameleons; Colour-Change in Amphibians—Common Frog; Colour-Change in Fishes—Plaice, Trout, Lumpsucker; Colour-change in Molluscs—Sea-Slugs; Colour-Change in Crustaceans—Æsop Prawn; Colour-Change in Insects—Peppered Moth, Small Tortoise-shell Butterfly - - - - - - - - - 289

Constant Special Protective Resemblance—Sloths, Pangolins; Coot, Moorhen, Grebes, Young Plovers; Australian Sea-Horses; Sea-Slugs; Stick-Caterpillars, Leaf-Butterflies, Buff-tip Moth, Stick- and Leaf-Insects; Spiders - - - 294

Variable Special Protective Resemblance—Leaf-Butterflies, Caterpillars of Early Thorn Moth - - - - - - - - - - - - - - - 300

CHAPTER XXVI.—ANIMAL DEFENCES—BODILY CHARACTERISTICS PRODUCING CONSPICUOUSNESS

CONSPICUOUSNESS:—Genuine Warning and Spurious Warning (Mimicry) - - 301

Genuine Warning—Skunk; Coral Snakes, Cobras, Puff-Adders, Rattlesnakes; Spotted Salamander, Nicaraguan Frog, Siamese Toad, Horned Toad; Weever-Fish, Globe-Fishes; Ascidians, Acorn-headed Worms; Sea-Slugs; Wasps, Hornets, Bees, Black-veined Brown, Magpie Moth, Conspicuous Caterpillars, Lady-bird; Spiders; Bristle-Worms; Planarian Worms; Sea-Anemones, Corals, Jelly-Fishes - - - - - - - - - - - - - - - 301

Spurious Warning (Mimicry)—Cuckoos, Orioles; American Snakes; Mimicking Butterflies, White Ermine Moth, Clear-wing Moths, Caterpillars of Lobster-Moth, Puss-Moth, and Hawk-Moths, Drone-Fly, Mimicking Beetles, Mimicking Grasshoppers and Crickets, Praying Mantis, Mimicking Plant-Bugs; Mimicking Spiders - - - - - - - - - - - - - - 309

CHAPTER XXVII.—ANIMAL DEFENCES—SPECIAL PRECAUTIONARY HABITS

Page

FEEDING AT FAVOURABLE TIMES: Nocturnal Animals—Night-Monkeys, Lemurs, Bats, Elephant, Hoofed Mammals, Gnawing Mammals, Edentates, Marsupials, Monotremes; Owl-Parrot, Kiwi; Geckos; Amphibians; Fishes; Cockroaches, Crickets, Moths, Fire-Flies; Marine Invertebrates - - - - - - - 318

Diurnal Animals—Herbivorous Mammals, Species exhibiting Warning Colours and Protective Resemblance - - - - - - - - - - - - - - 323

FEEDING IN SUITABLE PLACES: Species exhibiting Protective Resemblance, Wide Outlook, Proximity to Retreats - - - - - - - - - - - - - 324

Arboreal Animals—Evolution of Climbing Forms - - - - - - - - 325

Parachute Animals and Flying Animals—Their Evolution - - - - - - 327

CHAPTER XXVIII.—ANIMAL DEFENCES—PASSIVE DEFENCE

UNPALATABLENESS AND INDIGESTIBILITY—Associated with Warning Coloration 332

ARMOURED ANIMALS—Armadilloes, Pangolins, Porcupines, Hedgehogs, Spiny Ant-Eaters; Feathers and Leg-Scales of Birds; Armoured Reptiles; Extinct Armoured Amphibians, Ribs of Spanish Newt; Armoured Fishes; Shells of Molluscs; Beetles, Weevils, Caddis-Worms; Crabs, Rock-Lobster; Sea-Mouse, Porcupine Worm, Tube-dwelling Annelids; Skeletons of Moss-Polypes and Lamp-Shells; Plates and Spines of Sea-Urchins, Star-Fishes, &c.; Armoured Zoophytes—Hydroids, Organ-Pipe Coral, Sea-Anemones; Sponge Spicules; Armoured Animalcules—Foraminifera, Radiolaria, &c. - - - - - - 333

ROLLING-UP HABIT—Armadilloes, Pangolins, Porcupines, Hedgehogs; Mail-Shells; Trilobites, Wood-Lice - - - - - - - - - - - - - - 341

DEATH-FEIGNING HABIT—Dingo, Opossums, South American Fox; Tinamous, Rails; Lizards and Amphibians; Spiders; Beetles - - - - - - - 342

FECUNDITY OF ILL-DEFENDED ANIMALS—Rabbit, Flesh-Fly; Bats as Check to increase of Oak Procession-Moth - - - - - - - - - - - 345

CHAPTER XXIX.—ANIMAL DEFENCES—ACTIVE DEFENCE

AGGRESSIVE WEAPONS IN DEFENCE - - - - - - - - - - - 348

ACTIVELY DEFENSIVE WEAPONS: Mammals—Teeth of Apes and Monkeys, Use of Missiles by Baboons, Tusks of Walrus, Elephants, Rhinoceros, Wild Horses, Teeth of Hippopotamus and Swine, Antlers and Horns of Ruminants, Claws of Kangaroo, Stink-Glands of Skunk; Birds and Reptiles—Legs of Ostrich and Emeu, Rooks, Poisonous Lizards; Poison-Spines of Fishes; Poisoned Bite of Cone-Shells, Stinging-Organs of Sea-Slugs, Shells of Tridacna; Stings and Defensive Glands of Insects; Stink-Glands of Millipedes; Slime-Glands of Peripatus; Bristles of Bristle-Worms; Skin-Defences of Planarian Worms; Poison-Spines of Sea-Urchins; Stinging Organs of Zoophytes; Irritant Rodlets of Higher Animalcules - - - - - - - - - - - - - - 348

CO-OPERATION AMONG SOCIAL ANIMALS—Wild Horses, &c. - - - - - 362

CHAPTER XXX.—ANIMAL DEFENCES—RETREAT

Page

MAMMALS (Mammalia)—Monkeys and Baboons, Chamois, Antelopes, Rumination as facilitating Retreat, Importance of Dwellings and Refuges with reference to Retreat, Signalling Coloration - - - - - - - - - - - 363

BIRDS (Aves)—African Ostrich, Rails, Extinction of Dodo, Flight as a means of Retreat, Woodpeckers, Diving Birds - - - - - - - - - - 367

REPTILES (Reptilia)—Brittle Tails of Lizards, Importance of Cylindrical Shape in Snakes, &c. - - - - - - - - - - - - - - - - 370

AMPHIBIANS (Amphibia)—Wrestler Frog - - - - - - - - - - 371

INVERTEBRATES—Ink of Cuttle-Fishes, Detachable Foot-Region of some Land-Snails, Springing Molluscs, Ants and Bombardier Beetles, Use of Suspensory Threads (Spiders, Caterpillars, Slugs), Crustaceans, Sacrifice of Part of Body in Annelids, Possible Origin of Segmentation - - - - - - - - - 372

ANIMAL RESPIRATION—THE BREATH OF LIFE

CHAPTER XXXI.—ANIMAL RESPIRATION—GENERAL PRINCIPLES—BREATHERS IN WATER AND BREATHERS IN AIR

GENERAL PRINCIPLES—Nature of and Necessity for Breathing or Respiration, Breathing by General Surface, Special Breathing Organs - - - - - 376

BREATHERS IN WATER AND BREATHERS IN AIR—Process essentially the same in all cases, Relation between Plants and Animals as regards Breathing - - 378

CHAPTER XXXII.—ANIMAL RESPIRATION—VERTEBRATES THAT BREATHE IN WATER

Nature and Development of Gill-Clefts, Their possible origin in remote ancestral forms - - - - - - - - - - - - - - - - - - 381

FISHES (Pisces) AS BREATHERS IN WATER—Nature of Gills, Lampreys and Hags (Cyclostomata), Sharks and Rays (Elasmobranchii), Sea-Cats (Holocephali), Ordinary Bony Fishes (Teleostei) - - - - - - - - - - - 383

PRIMITIVE VERTEBRATES (Protochordata) — Lancelet, Ascidians or Tunicates, Acorn-headed Worms - - - - - - - - - - - - - 388

CHAPTER XXXIII.—ANIMAL RESPIRATION—NEMERTINES—MOLLUSCS WHICH BREATHE IN WATER

NEMERTINE WORMS (NEMERTEA)—Some resemblance to Vertebrates - - - 391

MOLLUSCS (Mollusca)—Mail-Shells, &c. (Protomollusca); Head-Footed Molluscs (Cephalopoda)—Cuttle-Fish, Pearly Nautilus; Snails and Slugs (Gastropoda)—Ormer, Keyhole Limpet, Whelk and Purple Shell, Common Limpet, John Knox's Limpet, Sea-Hare, Sea-Lemon, &c.; Bivalve Molluscs (Lamellibranchia)—Mussels, Cockles, Oysters, &c. - - - - - - - - - - - - 391

CHAPTER XXXIV.—ANIMAL RESPIRATION—JOINTED-LIMBED ANIMALS WHICH BREATHE IN WATER

CRUSTACEANS (Crustacea)—Common Lobster, Freshwater Crayfish, Common Prawn, Hermit-Crabs, Crabs, Mantis-Shrimps, Sand-Hoppers, Skeleton-

Page

Shrimps, Sea-Slaters, Water Wood-Louse, Mud-Shrimps, Apus, Water-Fleas, Mussel-Shrimps, Barnacles - - - - - - - - - - - - 400

KING-CRABS (Xiphosura) - - - - - - - - - - - - - 406

CHAPTER XXXV.—ANIMAL RESPIRATION—LOWER INVERTEBRATES WHICH BREATHE IN WATER

SEGMENTED WORMS (Annelida)—Bristle-Worms (Chætopoda)—Scale-Worms, Lugworm, Head-Gills of Tube-Dwellers; Leeches (Discophora) - - - 408

SIPHON-WORMS (Gephyrea) AND WHEEL-ANIMALCULES (Rotifera) - - - 410

MOSS-POLYPES (Polyzoa) AND LAMP-SHELLS (Brachiopoda) - - - - - 410

HEDGEHOG-SKINNED ANIMALS OR ECHINODERMS (Echinodermata)—Influence of the Skeleton on the Development of Breathing Organs, The Relation of the Water-vascular System to Breathing - - - - - - - - - 411

ZOOPHYTES (Cœlenterata)—Breathing by External and Internal Surfaces, Special Arrangement in some Sea-Anemones - - - - - - - - - 416

SPONGES (Porifera) AND ANIMALCULES (Protozoa) - - - - - - - 418

CHAPTER XXXVI.—ANIMAL RESPIRATION—BACKBONED ANIMALS WHICH BREATHE IN AIR

Nature and Development of Lungs, Aquatic Ancestry of Land Vertebrates - - 420

THE ORIGIN OF LUNGS—Swim-Bladder of Fishes—Bichir, Lung-Fishes - - 421

AMPHIBIANS (Amphibia)—Common Frog, Cæcilians, Lungless Amphibians - - 422

REPTILES (Reptilia)—Increase in Complexity, Mechanism of Breathing, Crocodiles, Snakes, Snake-like Lizards, Chameleons - - - - - - - - - 424

BIRDS (Aves)—Structure of Lungs, Air-Sacs, Mechanism of Breathing - - - 426

MAMMALS (Mammalia)—Structure of Lungs, Mechanism of Breathing, Cetaceans, Young Pouched Mammals - - - - - - - - - - - - 427

CHAPTER XXXVII.—ANIMAL RESPIRATION—BACKBONELESS ANIMALS WHICH BREATHE IN AIR

MOLLUSCS (Mollusca)—Lung-Snails and other Gastropods which breathe in air, Garden Snail, Black Slug, Pond-Snail, Trumpet-Snail - - - - - - 432

ARTHROPODS (Arthropoda)—Peripatus, Origin of Air-tubes - - - - - - 434

CENTIPEDES AND MILLIPEDES (Myriapoda)—Shield-bearing Centipede, Imperfect Development of Blood-System - - - - - - - - - - - - 435

INSECTS (Insecta)—Cockroach, Bees and Locusts; Aquatic Air-breathing Insects—Great Water-Beetle, Whirligig Beetles, Great Black Water-Beetle, Pond-Skaters, Water-Boatmen, Water-Scorpions, Rat-tailed Maggot, Common Gnat 437

ARACHNIDS (Arachnida)—Scorpions, Whip-Scorpions, Spiders, Mites - - - 442

CRUSTACEANS (Crustacea)—Land-Crabs, Wood-Lice - - - - - - - 443

LAND NEMERTINES (Nemertea), EARTH-WORMS AND LAND-LEECHES (Annelida), AND LAND PLANARIANS (Turbellaria) - - - - - - - - - - 444

CHAPTER XXXVIII.—ANIMAL RESPIRATION—AMPHIBIOUS VERTEBRATES

Page

FISHES (Pisces)—Eel, Carp, Tench, Mud-Skippers, Bleak, Roach, Loach, Snake-headed Fishes, Climbing Perch; Evolution of the Lungs of Backboned Animals, Lung-Fishes - - - - - - - - - - - - - - - - 447

AMPHIBIANS (Amphibia)—Hell-Bender, Giant Salamander, Olm, Siren Salamander; Common Frog - - - - - - - - - - - - - - - - 456

CHAPTER XXXIX.—ANIMAL RESPIRATION—AMPHIBIOUS INVERTEBRATES

MOLLUSCS (Mollusca)—Origin of Land-Snails and Slugs—Periwinkles, Apple-Snails, &c. - - - - - - - - - - - - - - - - 459

INSECTS (Insecta)—Net-Winged Insects (Neuroptera)—Stone-Flies, Dragon-Flies, May-flies, Alder-Flies, Caddis-Flies; Two-Winged Insects (Diptera)—Midges, Sand-Midges - - - - - - - - - - - - - - - - 462

CRUSTACEANS (Crustacea)—Shore-Crabs, Robber-Crab - - - - - - - 469

LIST OF ILLUSTRATIONS

HALF-VOL. IV

COLOURED PLATES

PAGE

THE CORAL SNAKE (*Elaps Corallinus*).
A Study by A. Fairfax Muckley ..... *Frontispiece.*

PROTECTIVE ANIMAL COLORATION.
A Study by A. Fairfax Muckley 312

HEAD-FOOTED MOLLUSCS (*Cephalopoda*) (after Merculiano and Jatta).
A Study by A. Fairfax Muckley 392

BLACK-AND-WHITE ILLUSTRATIONS

	Page
Group of Serpulæ	258
Dissection of Front End of an Earth-Worm	259
Dissection of Siphon-Worm (*Sipunculus*) (after Keferstein)	260
Moss-Polypes (after Kraepelin and Boas)	261
Crown Rotifer (*Stephanoceros*)	262
Vertical Section of Simple Sponge	265
A Proteus Animalcule (*Amœba*) surrounding a slender Alga (after Rhumbler)	269
Berry Animalcule (*Hæmatococcus pluvialis*) in resting and motile stages	273
Pallas's Sand-Grouse (*Syrrhaptes paradoxus*) (from Brehm)	280
Eggs of Ringed Plover (*Ægialitis hiaticula*) (from a photograph by R. A. L. Van Someren)	286
Crouching Young of Peewit (*Vanellus cristatus*) (from a photograph by R. A. L. Van Someren)	286
A Beetle (*Lithinus nigrocristatus*) which resembles Lichen	287
Upper Side of a Xenophorus Shell (from Chun)	288
Ptarmigan (*Lagopus mutus*), in winter plumage	290
Australian Sea-Horse (*Phyllopteryx eques*)	296
Caterpillars of Brimstone Moth (*Rumia cratægata*) in protective attitudes (after Poulton)	297
Hinder End of Caterpillar of Brimstone Moth (after Poulton)	297
Indian Leaf Butterfly (*Kallima inachis*)	298
American Skunk (*Mephitis suffocans*)	302
Rattle of Rattlesnake	304
Horned Toad (*Ceratophrys ornata*)	305
A Friar-Bird (*Philemon Timorlaoensis*) mimicked by an Oriole (*Oriolus decipiens*)	310
Caterpillars of the Lobster Moth (*Stauropus fagi*)	314
Heads of Nocturnal Animals	319
Diagram of varieties of Reptilian Armour, as seen in section (after Boas)	333
Nile Crocodile. Two scutes, covered by horny epidermal plates	333
Carapace and Plastron of a Tortoise (after Boulenger)	334
Method of Growth in Gastropod Shells	335
Growth of Bivalve Shell as seen in section	335
A spiny Sea-Snail (*Murex*)	336
Opercula of various Gastropods	336
Caddis-Worm Tubes of various kinds	337
The Northern Stone-Crab (*Lithodes maia*)	338
A Sea-Urchin (*Echinus lividus*), showing protective covering of spines	340
Part of Sea-Urchin Test, showing knobs for attachment of spines	340
A species of South American Fox (*Canis azaræ*)	343
THE FALLOW DEER (*Cervus dama*)	350
Horns of Gazelles	353
Poisonous Mexican Lizard (*Heloderma horridum*)	355

Page

Poison Spines of Fishes (after Günther) - 356
Sting of Bee (after Carlet) - - - - 358
Poison-Spine of a Sea-Urchin (*Asthenosoma urens*) (after P. and F. Sarasin) - 361
Baboons retreating from Wild Dogs (from Brehm) - - - - - - - - 364
The Chamois (*Rupicapra Tragus*) - 366
The Common Squirrel (*Sciurus vulgaris*) - 368
The Dodo (*Didus ineptus*) - - - - 369
Slug suspended by a Thread of hardened Slime - - - - - - - - 374
Front Part of Chick Embryo - - - 381
Californian Hag-Fish (*Bdellostoma*) - - 383
Diagram of Circulatory System in a Fish - 384
Diagram showing the Gill-Pouches of a Lamprey (*Petromyzon*) - - - - - 384
Circulatory and Breathing Organs of Hag (*Myxine glutinosa*) (after J. Müller) - 385
Horizontal Section through a Shark, showing the Gill-Pouches) (after Gegenbaur) 386
The Sea-Cat (*Chimæra monstrosa*) (after Garman) - - - - - - - - 387
Horizontal Section through the Breathing Organs of a Teleost (after Gegenbaur) - 388
Lancelet (*Amphioxus lanceolatus*) (after Boveri) - - - - - - - - 389
Section through an Acorn-headed Worm (*Balanoglossus*) (after Spengel) - - 390
Mail-Shell (*Chiton*) - - - - - - 392
Dissection of a Cuttle-Fish (*Sepia*) to show Gills (after Savigny) - - - - - 392
Ormer (*Haliotis*) dissected to show Gills - 394
Shells of various Sea-Snails (after Lang) - 394
Diagram of a Whelk (*Buccinum*) (after Lang) 395
Gill-Cavities of John Knox's Limpet and Common Limpet - - - - - - - 396
Diagram of Sea-Hare (*Aplysia*) (after Lang) 396
Diagrammatic Cross Section of Hind-gilled Snail - - - - - - - - 396
Sea-Lemon (*Doris*) (after Alder and Hancock) - - - - - - - - - 397
Freshwater Mussel (*Anodonta*) opened to show Gills - - - - - - - - 398
Freshwater Mussel (*Anodonta*) imbedded in mud - - - - - - - - 398
Gills of Lobster (*Homarus vulgaris*) - - 401
Gills of a Crab (after Gegenbaur) - - 404
Gills of Mantis-Shrimp and Sand-Hopper (after Milne-Edwards and Sars) - - 404
Mud-Shrimp (*Nebalia*) (after Milne-Edwards) 405
A Mussel-Shrimp (*Cypris*), enlarged - 406
King-Crab (*Limulus*) (partly after Ray Lankester) - - - - - - - - 406
Scale-Worm (*Polynoë*) (after Milne-Edwards) 408
Lugworm (*Arenicola piscatorum*), showing Gills - - - - - - - - - 409
A Tube-Worm (*Terebella*), showing Gill-plumes on Head - - - - - - 409

Page

Priapulus (after Ehlers) - - - - - 410
Mouth-Area of a Sea-Urchin (*Echinus esculentus*) (from Kükenthal) - - - 412
Cross Section through Arm of Star-Fish (from Kükenthal) - - - - - 413
Heart-Urchin (*Spatangus purpureus*) - 415
Dissection of Sea-Cucumber (after Ludwig, simplified) - - - - - - - - 416
Diagrammatic Vertical Section of a Sea-Anemone - - - - - - - - 417
Swim-Bladder of Bichir (*Polypterus*), diagrammatic - - - - - - - - 421
Sections through Lungs, showing Ingrowth of Folds (after Boas) - - - - - 424
Head of Crocodile to show Breathing Arrangements (after Boas) - - - 425
Lungs of a Chameleon (after Wiedersheim) 425
Lungs and Air-Sacs of a Bird (after Heider) 426
Convoluted Windpipe of a Crane - - 427
Air-Passages of Lungs of Man - - - 428
Mouth, Nose, &c., of Man, in Section - 429
Lung of Land-Snail (*Helix*) (after Hatschek and Cori) - - - - - - - - 433
Breathing Organs of Shield-bearing Centipede (*Scutigera*) (after Haase) - - 436
Air-Tubes of Cockroach (*Periplaneta orientalis*) (after Hatschek and Cori) - - 438
Dissection of Honey-Bee (*Apis mellifica*) (after Leuckart) - - - - - - 439
The Drone-Fly (*Eristalis tenax*) and its Larva, the Rat-tailed Maggot - - 441
Larva and Pupa of Common Gnat (*Culex pipiens*), enlarged - - - - - 442
Mygale (partly dissected) from below - 443
The Mud-Skipper (*Periophthalmus Koelreuteri*) - - - - - - - - 448
Roach (*Leuciscus rutilus*) and Bleak (*Alburnus lucidus*) - - - - - 449
Indian Snake-headed Fish (*Ophiocephalus*) 451
Climbing Perch (*Anabas scandens*) - - 452
Dissection of a Bitterling (*Rhodeus amarus*) 452
Roof of Gill-Cavity in a Species of Periwinkle (*Littorina rudis*) (after Pelseneer) 460
Apple-Snail (*Ampullaria*) (after Semper) - 461
A Stone-Fly (*Pteronarcys*) (after Newport) - - - - - - - - - 464
Air-Tubes of Rectal Gills in Dragon-Fly Nymph (after Oustalet) - - - 465
Nymph of Common May-Fly - - - 465
Hinder Part of Nymph of a May-Fly (*Cloëon dipterum*) (after Zimmermann) - 465
Crustacean-like Nymph of a May-Fly (*Prosopistoma*) (after Vayssière) - - 466
Stages in Life-History of a Sand-Midge (*Simulia*) (after Verdat) - - - 468
Diagrammatic Cross Section through Breathing Organs of Robber Crab (*Birgus latro*) (after Semper) - - 469

CHAPTER XXIII

THE FOOD OF ANIMALS—OMNIVOROUS ANNELIDS, SIPHON-WORMS, LAMP-SHELLS, MOSS-POLYPES, AND WHEEL-ANIMALCULES

SEGMENTED WORMS (ANNELIDA)

The ANNELIDS include Leeches (Discophora) and Bristle-Worms (Chætopoda). The former are carnivorous, and have already been dealt with (pp. 147–149), and the same is true for many rapacious marine worms belonging to the latter group, as, for example, the Sea-Centipede (*Nereis*) (pp. 146, 147).

OMNIVOROUS BRISTLE-WORMS.—These comprise marine, fresh-water, and terrestrial forms. The marine species include a number of worms which are entirely devoid of biting structures and burrow in sand or mud, which they swallow in order to extract the nutritive animal and vegetable matter present. The same habit has already been described (p. 246) for the Acorn-headed Worm (*Balanoglossus*), one of the lowest animals having any claim to be considered a member of the Vertebrata. A good example of marine worms which feed in this way is the Lob-Worm (*Arenicola*) (see vol. i, p. 430), common on British shores between tide-marks where mud or mud-containing sand occurs. This is a good-sized cylindrical form with broad front end, and may attain a length of some 8 inches. It burrows in the sand to a depth of about 2 feet, eating its way through, so to speak, and from time to time comes to the surface for the purpose of ejecting the sand which has passed through its body. This is the origin of the little coils of mud or sand known as "worm-castings" which are commonly seen upon the shore.

A considerable number of marine bristle-worms have given up an active life and taken to live in tubes of various kinds, these either consisting entirely of material exuded from the surface of the body and hardened into horny or shelly substance, or of

foreign particles, such as sand-grains, glued together by a sticky secretion. A typical example is afforded by the genus Serpula (fig. 466), which makes and inhabits calcareous white tubes, twisted masses of which are often found adhering to rocks, oyster-shells, &c. It is clear that a tube-dweller like this has to make special provision for breathing and feeding, and this is here effected in an interesting manner. On watching a living Serpula placed in a vessel of sea-water the head end will soon be seen to protrude. First of all a sort of conical stopper (operculum), which closes and protects the mouth of the tube, is pushed out, and then follow two brightly-coloured plume-like outgrowths from the head. These are covered with cilia, which set up currents in the surrounding water, as a result of which breathing is provided for, while at the same time a constant stream of edible particles is directed into the mouth. A common and, when expanded, very attractive-looking worm (*Pomatoceros triqueter*) that abounds on the British coast, lives in a small wavy tube attached to a stone or other firm body. One end of the tube tapers to a point, while the aperture is overhung by a sharp projecting spine from which a prominent ridge runs backwards. Equally common is a still smaller tube-worm (*Spirorbis*), which inhabits a calcareous tube coiled into a flat spiral, and adhering to brown sea-weeds or other suitable objects. Other tube-dwellers will be considered when animal habitations are described.

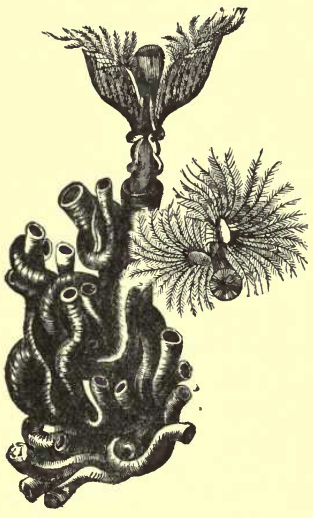


Fig. 466.—Group of Serpulæ. Two individuals are projecting from their tubes

Great interest attaches to the widely-distributed group of Earth-Worms, the habits of which, so far as British species are concerned, were first studied in detail by Darwin, the results being embodied in his classic work on the subject.

A number of species are native to Britain (a common sort being *Lumbricus herculeus*), all of which live in much the same way. Examination of one of them shows the complete absence of jaws, and the food chiefly consists of earth which is constantly swallowed for the sake of the organic matter it contains. An

earthworm practically eats its way through the ground, and the earth which has passed through its body is from time to time deposited on the surface in the form of "castings", much as in the case of the Lob-Worm (p. 257). By carefully weighing the castings deposited on a known area Darwin came to the conclusion that in many parts of England 10 tons per acre of soil annually pass through the bodies of these creatures. Earth-worms also devour small pieces of vegetable or animal matter which come in their way. There are several points of interest in the structure of the digestive organs (fig. 467). The *mouth* opens into a small pouch which can be protruded to the exterior to aid in the taking in of food, and this followed by a muscular *pharynx* which appears to exert a sort of sucking action. Next comes a slender *gullet* into which open glands secreting particles of carbonate of lime that perhaps help to neutralize organic acids present in the soil, and the posterior end of this dilates into a rounded *crop* in which food is temporarily stored, and which again communicates with a rounded muscular *gizzard*, enclosing small stones, much as in a bird. These help to grind up the food, and thus make up for the absence of jaws. The rest of the digestive tube consists of the long thin-walled *intestine*, in which the process of digestion is completed. A further fact of interest, observed by Darwin, is that a digestive fluid is poured from the mouth upon bits of vegetable matter, the preparation of which, therefore, begins outside of the body altogether.

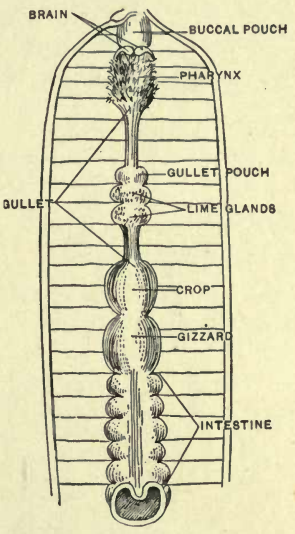


Fig. 467.—Dissection from above of front end of an Earth-Worm

SIPHON-WORMS (GEPHYREA)

These are jawless marine worms, some of which are omnivorous sand-swallowers devoid of bristles. A good example is the Common Siphon-Worm (*Sipunculus*) (see vol. i, pp. 433, 434), found burrowing in sand on many parts of the British and other coasts. The front part of the body is narrow, and when fully expanded is seen to end in a horse-shoe-shaped circlet of short *tentacles*, within which is the *mouth*. The greater part of

the gut consists of a long very thin-walled *intestine*, which pursues a spiral course to the hind end of the body, and then twines back upon itself to terminate upon the upper side of the body not far from the front end (see fig. 468). It is always full of sand, and siphon-worms of the sort described play much the same part in regard to the sand of the sea that earth-worms do as regards the earth covering the land. Shipley (in *The Cambridge Natural History*) makes the following remarks on this head:—"The rate at which the sand passes through the body of *Sipunculus* is unfortunately unknown, but that at any one moment a considerable quantity is contained in the intestine is shown by the fact that the average weight of five specimens of *S. nudus* [a large species] from Naples, taken at random, was 19.08 grms., whilst the average weight of sand washed out of their alimentary canal was 10.03 grms".

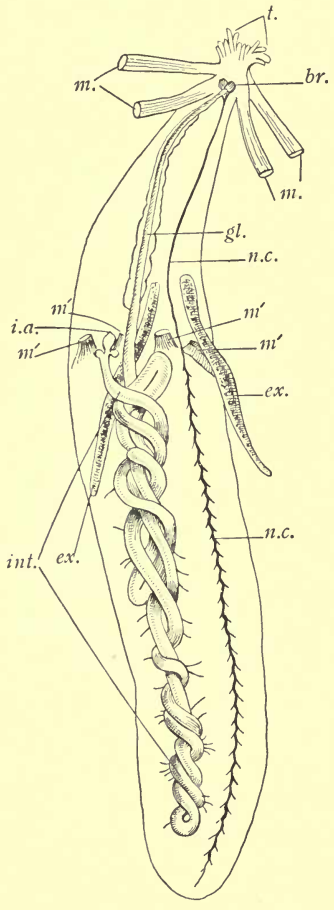


Fig. 468.—Dissection of Siphon-Worm (*Sipunculus*)

t, Tentacles; *m m* and *m' m' m' m'*, muscles which pull in front end of body, cut through; *gl.* gullet; *int.* intestine; *i.a.* intestinal aperture; *ex. ex.* excretory tubes; *br.* brain; *nc*, nerve cord.

Three groups of specialized worms now claim our attention, *i.e.* Lamp-Shells (Brachiopoda), Moss-Polypes (Polyzoa), and Wheel-Animalcules (Rotifera). All the animals included in these groups are omnivorous, feeding upon the minute organisms and nutritive particles brought to them by ciliary currents (see pp. 243, 244).

LAMP-SHELLS (Brachiopoda)

The animals here included were once confounded with the bivalve Molluscs (p. 248), chiefly because they are enclosed in a shell composed of two pieces. A typical Lamp-Shell (see vol. i, p. 439) is attached to some firm body, either by the substance of one shell or by means of a sort of stalk projecting at one end. As has already been exemplified in other groups, sedentary or

fixed forms commonly get their living by setting up currents in the surrounding water. In this case the current-producing organs are two often complicated "arms", fringed outgrowths from the mouth-region richly covered with cilia, the movement of which produces food-bearing streams of sea-water, which are conducted along grooves to the mouth. All Brachiopods are marine, and at the present time they exist in greatly-diminished numbers, though in older geological epochs they were dominant forms of marine life.

MOSS-POLYPES (POLYZOA)

The MOSS-POLYPES are small animals, nearly always fixed, and in most cases living in colonies produced by budding (vol. i, pp. 436–438). Most of them are marine, but several kinds are inhabitants of fresh water. A great many species are found

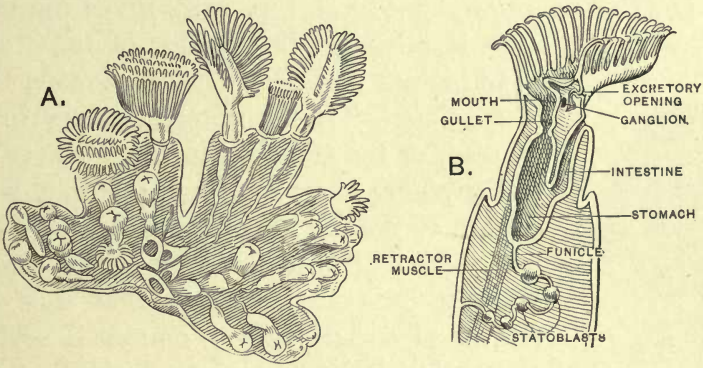


Fig. 469.—Moss-Polypes (enlarged)

A, Small colony of *Lophopus crystallinus*, showing some individuals fully extended, and others in different states of retraction. B, Diagram of a single individual of *Plumatella*, cut through centre of body.

attached to sea-weeds, &c., along the British coasts, and there are also some native species in our streams and lakes. The projecting end of each individual bears both openings of the U-shaped *gut*, and also a crown of ciliated *tentacles* (lophophore) which has been compared to the "arms" of the preceding group, and which has at any rate the same chief function, the setting up of food-bearing currents in the surrounding water (fig. 469).

WHEEL-ANIMALCULES (ROTIFERA)

These minute creatures mostly live in fresh water, including puddles, roof-gutters, and the moisture saturating damp vege-

tation, especially mosses, but some are to be found in brackish water or in the sea. They present a great variety in form and habit; the majority are free-swimming, but others live in tubes constructed by themselves, and others again are parasitic. A typical free-living form has elsewhere been briefly described (vol. i, pp. 434, 435). In by far the greater number food is brought to the mouth by ciliary action, set up by variously-arranged cilia placed on the front end of the body and sometimes situated on special lobes. The name "wheel-animalcule" was given by early observers, who studied species in which there are two circlets of cilia placed on adjacent projections. The successive movement of the cilia on these projections produces an optical illusion, and suggests the movement of a wheel. Thus, Baker, writing about 1744 to the then President of the Royal Society concerning his observations on the form already described, the Rose-coloured Rotifer (*Philodina roseola*) (see vol. i, p. 434), gives the following account, which, though it mistakes the nature of the "wheels", which is not surprising, clearly grasps their use in feeding:—"If the water standing in gutters of lead, or the slimy sediment it leaves behind, has anything of a red colour, one may be almost certain of finding them therein, and, if in summer, when all the water is dried away, and nothing but dust remains, that dust appears red, or of a dark-brown, one shall seldom fail, on putting it into water, to discover multitudes of minute reddish globules, which are indeed the animals, and will soon change their appearance in the manner just now mentioned. . . .

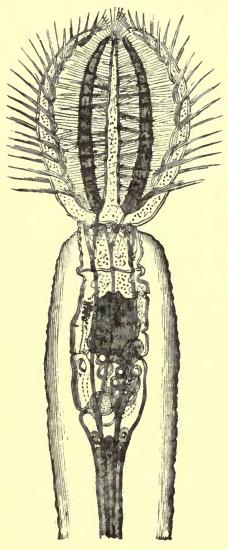


Fig. 470.—Crown Rotifer (*Stephanoceros*), enlarged

"A couple of circular bodies, armed with small teeth like those of the balance-wheel of a watch, appear projecting forwards beyond the head, and extending sideways somewhat wider than the diameter thereof. They have very much the similitude of wheels, and seem to turn round with a considerable degree of velocity, by which means a pretty rapid current of water is brought from a great distance to the very mouth of the creature, who is thereby supplied with many little animalcules and various particles of matter that the waters are furnished with."

All wheel-animalcules, however, are not entirely limited, as regards food-supply, to what is brought by ciliary currents. Some of them (fig. 470), such as the beautiful Crown Rotifer (*Stephanoceros*), possess a number of pointed projections from the head-region, which are actively used to surround small animals or other food substances, and their efficiency may be increased by the presence of slender bristles, as in the Flower Rotifer (*Floscularia*). The *mouth* of a wheel-animalcule leads into a funnel-shaped *pharynx* lined with cilia, and this again is continuous with a powerful muscular *gizzard* (mastax) imbedded in the walls of which are hard jaw-like pieces used for chewing. In many cases these jaws can be protruded from the mouth and employed for seizing food, even, it may be, for attacking other rotifers with a view of adding them to the bill of fare.

CHAPTER XXIV

THE FOOD OF ANIMALS—OMNIVOROUS ECHINODERMS, SPONGES, AND ANIMALCULES—ANIMALS WHICH FEED LIKE GREEN PLANTS

ECHINODERMS (ECHINODERMATA)

The large and characteristic phylum of ECHINODERMS (p. 153) embraces Star-Fishes, Sea-Urchins, Sea-Cucumbers (*Holothurians*), and Crinoids (Sea-Lilies and Feather-Stars). The first of these are essentially carnivorous, and have already been dealt with (p. 153), but the remainder, being largely omnivorous, claim some attention here. They exemplify feeding by sand-swallowing and the action of ciliary currents, both being common modes of obtaining nutriment, as has already been shown.

SEA-URCHINS (see vol. i, p. 456) are spheroidal or flattened forms, covered with movable *spines*, and with the *mouth* placed on the under surface. Five pointed *jaws*, which grow continuously, like the front teeth of a rabbit, are often but not always present. The thin coiled *intestine* is, in many species, found on dissection to be full of sand, from which the organic matter is extracted just as in a Lob-Worm (p. 257) or Siphon-Worm (p. 259).

SEA-CUCUMBERS (*Holothurians*) (see vol. i, p. 462) are worm-like animals with thick leathery skins. The *mouth* is placed at the front end, and is surrounded by a circlet of *tentacles*, the shape of which varies a great deal in different species. They are generally used for shovelling sand or mud into the mouth, but in some cases are long and branched, so that when fully extended they can be employed as a sort of net in which food floating in the surrounding water gets entangled.

The commonest existing CRINOID is the Feather-Star (*Comatula*) (see vol. i, p. 460), which consists of a central *disc*, from which ten feathery *arms* radiate, the plume-like appearance of

these being due to a series of short branches (pinnules) with which each of them is beset on either edge. The Feather-Star is commonly found moored to some firm object by a circlet of filaments attached to the back of the central disc. The *mouth* is situated in the centre of the body, and from it ciliated *food-grooves* run along the arms, sending branches along the pinnules. The currents set up by the action of the cilia flow along the grooves to the mouth, into which they carry all sorts of minute organisms and other particles serving as food.

The other members of the Crinoidea are Sea-Lilies (see vol. i, p. 460), which live in the deep sea, and may be compared to Feather-Stars attached to various objects by long stalks. Their way of feeding is precisely the same.

Passing over the members of the phylum CŒLENTERATA, which in typical cases are actively carnivorous (see p. 155), we come to the two lowest groups in the animal kingdom, *i.e.* SPONGES and PROTOZOA, the species included in which are mostly or largely omnivorous.

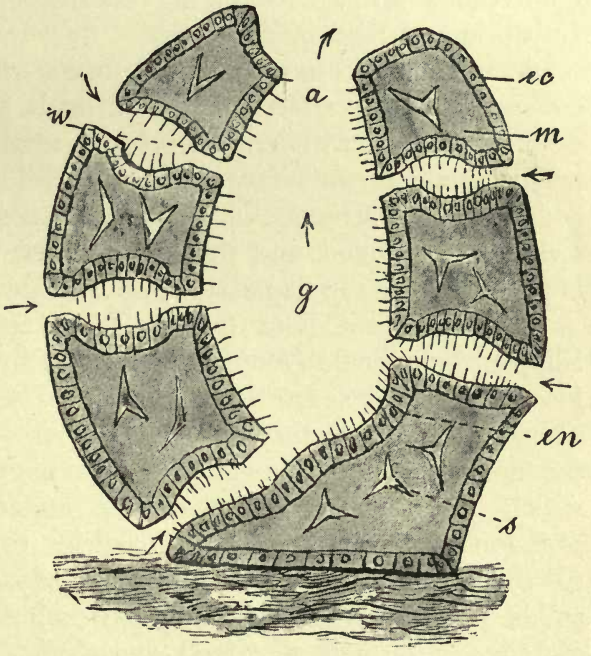


Fig. 471.—Vertical Section of Simple Sponge (enlarged and diagrammatic)
ec, External body-layer; *m*, middle body-layer, with spicules, *s*; *en*, internal body-layer, made up of flagellated cells and extending into the canals (*w*), which pierce the side-wall of the body, opening into the central cavity, *g*, that also communicates with the exterior by a large aperture, *a*. The arrows indicate the course taken by the currents of water which traverse the body.

SPONGES (PORIFERA)

SPONGES are either simple or colonial animals of sluggish habit, which live attached to stones or other firm objects. The structure of a simple Sponge has elsewhere been described (vol. i, p. 484), and it need only be stated here that the body is vase-shaped, with its walls perforated by numerous holes. The lining of the vase is composed of a layer of remarkable

collar-cells, from each of which projects a thread of living substance (protoplasm) which constantly describes whip-like movements, and has therefore been termed a *flagellum* (L. *flagellum*, a whip). By the combined action of all the flagella, currents are produced in the surrounding water, which flow through the holes in the body-wall and then to the exterior through the mouth of the vase (fig. 471). These currents bring with them food of mixed vegetable and animal nature, as in so many other cases where this mode of getting a living is adopted. Colonial Sponges may assume all sorts of shapes, and their structure is often very complicated, but in all cases the food is obtained as in the simple case described.

ANIMALCULES (PROTOZOA) (see vol. i, fig. 301)

We have here a host of microscopic or minute forms, the chief omnivorous species belonging to the two important groups of Infusoria and Rhizopoda.

INFUSORIA.—These include forms which are more or less covered with the short vibratile threads known as *cilia*, and also others provided with one, two, or a small number of the longer protoplasmic threads termed *flagella*. The former set of species constitute the Ciliata, which are either simple or colonial, free-swimming or fixed, and the same variety in character and habit is presented by the flagellate species, embraced in the Flagellata.

Among the Ciliata (see vol. i, p. 489) the free-swimming Slipper Animalcule (*Paramœcium*) and the fixed Bell Animalcule (*Vorticella*) will serve as examples. The Slipper Animalcule is a small active creature of oval shape, which is just visible to the naked eye. It moves actively about by means of the cilia which cover its body, and on the under side is a ciliated depression which conducts food particles to the mouth and thence to the semifluid interior of the body. With each batch of solids a small amount of water passes in, and the food-containing globule is termed a "food-vacuole". The *food-vacuoles* are moved slowly round the inside of the animal, digestion and absorption going on meanwhile, and the undigested remnants are cast out at a point not far from the mouth. The Bell Animalcule, when fully expanded, is shaped like a blunt cone attached by a stalk at the narrow end, while the broad part bears a wreath of cilia arranged in a short spiral. These produce a sort of

whirlpool by which food is carried down into a ciliated funnel at the bottom of which the mouth is placed, and through this the nutritious particles, together with water, are conducted down a short gullet into the soft interior of the body. The remaining details are much as in the Slipper Animalcule.

The Flagellata (see vol. i, p. 489) include a host of minute creatures, many of which can only be studied by means of a powerful microscope. Suitable examples are Euglena, Collar Animalcules, and Monads.

Euglena.—Stagnant pools, or puddles of fresh water, and also the moisture accumulating in roof-gutters, are often of a greenish colour, as a result of the presence of immense numbers of Euglenæ. Each individual is somewhat sausage-shaped, but the writhing, worm-like movements which are constantly going on alter its appearance from time to time. A long, quivering *flagellum* projects from one end of the body, and at its base is a minute mouth from which a short, funnel-like gullet projects into the soft interior substance of the body. The flagellum sets up movements in the surrounding water by which minute food particles of various kinds are drawn into the mouth. Euglena is green in colour, owing to the presence of green pigment identical with that found in the leaves of ordinary plants. There is also a red "eye-spot" near the front end.

Collar Animalcules are simple or colonial forms, in which each individual is comparable to a collar-cell of a sponge placed on a stalk and leading an independent existence. As in Euglena, small particles of food are drawn to the neighbourhood of the animal by the movement of the flagellum. Some of these stick to the outside of the collar and are carried down to a soft spot equivalent to a mouth.

Monads are excessively minute Flagellates which swarm in putrefying infusions. A typical species is the Springing Monad (*Heteromita*), in which the body is pear-shaped and bears two long flagella. One of these is directed forwards, and serves as the active agent of locomotion, while the other is trailed behind. This is one among very numerous cases in the Protozoa where the food does not consist of solid particles taken in through a mouth. In fact the Springing Monad would seem to be devoid of a mouth, and feeds upon the nutritious substances dissolved in the infusion where it lives, which are able to diffuse into the

interior of the body through the delicate membrane by which it is invested.

Rhizopods (see vol. i, p. 489).—These are animalcules of lower grade than the preceding group, for the body is not covered by a membrane conferring a definite shape, and is devoid of the specialized threads (cilia and flagella) which, as we have just seen, play such an important part in the feeding of higher Protozoa. The simplest and at the same time most instructive example is the Proteus Animalcule (*Amœba*), a microscopic creature found in all sorts of places, especially on mud and water-plants in ponds and ditches. Its body is a mere particle of living substance (protoplasm), semifluid in consistency, and continually altering its shape when the animal is in an active healthy state, a circumstance which has suggested both the common and scientific names. On watching a living amœba, which has been placed in a drop of water under the microscope, its body will be observed to flow out from time to time into bluntish lobes, which, however, are in no sense permanent structures, for they are sooner or later drawn back so as to form part of the general body. Each such lobe is somewhat inappropriately called a "false-foot" (pseudopod), and its use is to help in locomotion and the taking in of food. Amœba possesses neither mouth nor internal digestive cavity, for in the absence of a firm bounding membrane nutritive particles can be taken in at any point, being engulfed by the pseudopods. The body, so to speak, flows round the food, which is of varied nature, consisting of microscopic plants and animals, together with organic particles of different kinds. With these a good deal of water is taken into the body, and food-containing globules (food-vacuoles) result, much as in a Slipper Animalcule or Bell Animalcule (see vol. i, p. 492). These move round in the interior of the animal and are gradually digested, the innutritious or undigested parts being cast out of the body wherever most convenient. It might almost be said that an amœba flows away from the remains of its meals. The Proteus Animalcule has been observed feeding upon certain lowly green plants (*algæ*) much longer than itself, and the tactics pursued in order to get these entirely within the body are extremely interesting (fig. 472). There is, of course, no difficulty in flowing round one end of such a plant, and the next move is for a pseudopod to be pushed along it, and then

bent back so as to make a kink or bend in the filament. By a continuance of this sort of manœuvring the animalcule often succeeds in coiling up the alga into a compact mass of convenient shape, adapted for easy digestion. In briefly dealing with human anatomy and physiology it was pointed out (vol. i, p. 39) that the circulatory fluids of the body, blood and lymph, contain innumerable microscopic bodies, the *white corpuscles*, which progress by creeping movements, in the same way as just

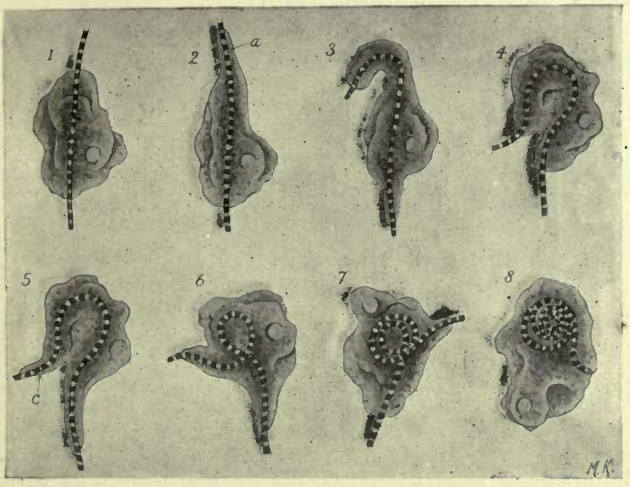


Fig. 472.—A Proteus Animalcule (*Amœba*) surrounding a slender alga. The numbers (1–8) indicate the successive stages in the process. Much enlarged.

described for the Proteus Animalcule. Nor does the resemblance between the two stop here, for the white corpuscles feed by taking in particles bodily, a fact of great importance, and one which has caused them to receive the name of "eating-cells" (phagocytes—Gk. *phagein*, to eat; *cytos*, a small box, hence a cell). The white corpuscles, indeed, play a very important part in most if not all groups higher in the scale than Protozoa, for they perform the functions of scavengers and police. In human beings, for example, they attack and devour disease-germs which have made their way into the system, and the upshot of many cases of infectious disease depends upon the result of a vigorous contest between corpuscles on the one hand and germs on the other.

Some very interesting freshwater Rhizopods are practically amœbæ provided with shells, and a shell-bearing group somewhat more distantly related is that of the Foraminifera, members of which abound in the sea, and are also found to a less extent

in the waters of the land. In these animalcules the pseudopods are exceedingly slender, and united together into a viscid net-work by which the food is entangled. The same device is present in the shelless Fungus-Animals (Mycetozoa), of which one common kind (*Æthalium*) is found in the form of good-sized branching yellow flakes ("flowers of tan") creeping upon heaps of spent tan. Each flake has been constituted by the fusion of a large number of minute organisms resembling amœbæ, and is therefore in reality of a compound nature.

ANIMALS WHICH FEED LIKE GREEN PLANTS

Some account has now been given of both food and way of feeding in typical carnivorous, vegetarian, and omnivorous animals. To complete and round off this part of the subject some notice is necessary of certain animals, belonging to various groups, which subsist partly or entirely after the manner of *green plants*. An average ANIMAL feeds upon very complex food, part of which is in the form of solid particles, for the reception of which an internal digestive cavity is provided. In all the forms so far described the food is complex as regards its chemical nature, though it may be entirely liquid, as in Tape-Worms, &c., and examples have also just been given of animalcules devoid of any digestive cavity. PLANTS, on the other hand, subsist entirely upon gaseous and liquid food, though to this there are partial exceptions. And though certain *colourless plants*, of which *fungi* (*e.g.* mushrooms, toadstools, mildews, moulds) are familiar examples, so far approximate to animals that they live upon more or less complex organic substances, yet typical *green plants* differ markedly from average animals in that their food is simple as regards chemical composition. The power such plants possess of building up complex living substance (protoplasm) from water, carbonic acid gas, and dissolved mineral substances, depends upon the presence of the characteristic pigment called *leaf-green* (chlorophyll). Examination of one of the thin leaves from a moss-plant will show that it is made up of *cells* (vol. i, p. 469) bounded by membranes (cell-walls) and containing living substance (protoplasm). Imbedded in the protoplasm are a number of rounded granules of bright-green colour. These are *chlorophyll-bodies*, and each of them is in reality a specialized bit of protoplasm through which leaf-green is diffused. Similar

bodies are present in the green parts, especially the leaves, of all the plants which make up the conspicuous part of vegetation, though in some lowly forms there may be chlorophyll-bodies of very different shape. That, however, is an unimportant detail, the essential fact being that leaf-green in some way enables the living substance which it permeates to build up the simple chemical compounds already enumerated into complex organic substance. In an ordinary land-plant the requisite carbonic acid gas (CO_2) is supplied by the air, while the water and mineral matters are taken up from the soil. In a word, green plants bridge over, as it were, the gap between the non-living mineral kingdom and living organisms. The upbuilding process associated with the presence of chlorophyll is dependent upon *light*, and this pigment, in some way not clearly understood, enables the energy of the sun's rays to be used for the purpose.

The nutrition of green plants has been mentioned here because there are some animals in which chlorophyll is present, and which therefore are partly, or in some cases it would seem entirely, able to subsist upon carbonic acid gas, water, and mineral salts. A very interesting example is afforded by a small marine flat-worm belonging to the group of Planarian Worms (Turbellaria) (see vol. i, pp. 445–447). This creature (*Convoluta Roscoffensis*) is found in large numbers floating in the shore-pools at Roscoff, on the French coast, and is coloured green by the presence of numerous chlorophyll-bodies, which enable it to live entirely after the manner of a green plant. The Convoluta belongs to a carnivorous group, and is no doubt descended from forms which depended upon animal food. A gradual change of habit has, however, taken place, and this is associated with corresponding modification of structure. It is, however, doubtful whether the chlorophyll-bodies are really an actual part of their possessors. Some authorities regard them as resulting from the specialization of microscopic green plants (algæ), the ancestors of which acquired the curious habit of living inside an animal.

Well-known instances of the presence of chlorophyll are found in the phylum of ZOOPHYTES (Cœlenterata). A case in point is that of the Green Freshwater Polype (*Hydra viridis*) commonly found adhering to water-weeds in ponds and streams. Hydra has already been described in some detail (vol. i, pp. 465–473), and it need only be remarked here that the body is

a tube closed at one end, by which attachment is effected, and open at the other, the aperture being the *mouth*, around which a number of slender *tentacles*, used for catching food, are arranged in a radiating manner. The animal is indeed little more than a living stomach. The body-wall consists of two layers, an outer (ectoderm) and an inner (endoderm), with which latter we are here concerned. For imbedded in this layer are a large number of *chlorophyll-bodies*, which almost certainly enable the animal to live partly upon simple inorganic substances, though the chief food consists of small animals captured by means of the tentacles. Here again it is considered by some that the green granules are really minute plants, but this remains to be proved. Saville Kent (in *The Great Barrier Reef of Australia*) expresses the opinion that many kinds of coral-animals live entirely in a plant-like way, an opinion founded on the absence of animal substances in the digestive cavities of specimens examined by him. The matter needs careful investigation, and it is quite possible that these creatures may turn out to subsist in the duplex manner supposed to be characteristic of the Green Hydra. The fact that coral-animals are often of the most brilliant colours other than green is no difficulty, for even in some green plants chlorophyll is disguised by the presence of other pigments, of which a good instance is that of the common brown sea-weeds. If a bit of such a plant be immersed in spirit for a short time it will turn green, as the brown colouring matter is quickly dissolved out; and perhaps chlorophyll is not the only pigment which possesses the remarkable properties above described.

Passing over the case of the Freshwater Sponge (*Spongilla*), which is of a green colour owing to the presence of chlorophyll, we come to certain animalcules (Protozoa) in which this pigment is present to a greater or less extent. Some of these are undoubted animals, and Euglena, which has been described above (p. 267), is a good example of such cases. It partly feeds by taking in solid particles through a minute mouth, and also contains chlorophyll-bodies, which no doubt enable it to utilize the simple substances upon which green plants entirely subsist. From a case like this we can pass to others where it is difficult, if not impossible, to say whether we are dealing with plants or animals. A familiar instance is afforded by a microscopic form which often abounds in puddles, water-butts, &c., imparting a greenish tinge

to the water. It has no popular name, but to avoid using the somewhat long-winded scientific one (*Hæmatococcus pluvialis*) (fig. 473), we may perhaps call it the Berry Animalcule. It is to be found both in a "resting" and a "motile" stage. In the former condition it appears as a minute sphere, either entirely green, or more or less red from the presence of a second pigment in addition to the chlorophyll. The sphere owes its definite form to the presence of a delicate bounding membrane (cell-wall) composed of a substance (cellulose) characteristic of plants, though not entirely limited to them. Cellulose is closely related to starch, and ordinary cotton is a very pure form of it. There is no trace of mouth or digestive cavity, and the food consists merely of carbonic acid gas, water, and simple mineral salts, and if our knowledge of the Berry Animalcule were limited to this resting-stage we should undoubtedly look upon it as a low green plant.

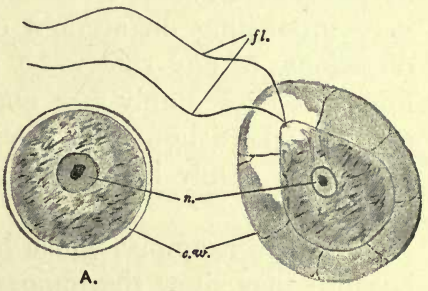


Fig. 473.—Berry Animalcule (*Hæmatococcus pluvialis*), greatly enlarged. A, Resting stage; B, motile stage: *c.w.* cell-wall; *n.* nucleus; *fl.* flagella.

But we also find it in a "motile" condition, when it is capable of executing active swimming movements. Under these circumstances the living substance of the body is pear-shaped, with a couple of whip-like flagella projecting from the clear narrow end, and effecting active locomotion by means of their lashing movements. In this case the cell-wall may either be entirely absent or it may be seen investing the body some little distance from the pear-shaped body-mass, and pierced by the projecting flagella. As before, no special digestive organs are present, while the food and way of feeding are entirely plant-like. Considered by itself, we should be justified in considering the Berry Animalcule as a plant, and its powers of active movement in one stage of the life-history is no particular bar, for many lower green plants (algæ) about whose nature there is no question propagate by means of minute actively-moving "zoospores" of fairly similar character. Most botanists accordingly claim this organism as a plant, and it will be found described as such in standard text-books of botany. Many zoologists, however, look upon the Berry Animalcule as an animal which feeds like a plant, basing their

such as "precautionary measures" and "passive defence", the defence is of purely unconscious kind, and has been determined by evolutionary factors working irrespective of the will or knowledge of the animal. Even when an animal actively defends itself against attack it does not follow that it has any clear idea of what the aggressor is after, though it must be admitted that the latter has more clearly-cut ideas on the subject.

The following scheme will perhaps serve to illustrate the main principles of animal defence in the limited sense indicated above, and it will be followed by detailed description of illustrative instances, though space forbids anything like a complete review of the animal kingdom under each heading.

I. PRECAUTIONARY MEASURES

Under this heading will be grouped those various defensive measures which tend to obviate attack altogether, and these fall pretty naturally under (1) Bodily Characteristics, and (2) Mode of Life or Habits.

(1) Bodily Characteristics. — These may be considered in so far as they result in (*a*) Inconspicuousness, and (*b*) Conspicuousness. The first is obvious and the other will be clear after explanation.

(2) Mode of Life.—Defence may be promoted by (*a*) Feeding at favourable times, (*b*) Feeding in favourable places.

Supposing, however, that attacks are actually delivered, their intention may be frustrated by means falling under a second large heading.

II. RESISTANCE

This may take the form of either (A) Passive Defence, or else (B) Active Defence.

(A) Passive Defence.—This may be effected by (1) Bodily Characteristics, or by (2) Special Habits, and not infrequently both contribute to the efficiency of the resistance offered. There is also (3) Fecundity as a defensive measure.

(1) Bodily Characteristics. — Of these perhaps the most important are — (*a*) Unpalatableness and Indigestibility, resulting from various peculiarities; (*b*) Possession of

Armour, as purely defensive arrangements may be broadly termed.

(2) SPECIAL HABITS, such, *e.g.*, as the Death-feigning Instinct, Rolling-up Instinct, &c.

(3) FECUNDITY as a means of defending the species.

(B) ACTIVE DEFENCE.—This employs the method of counter-attack, and includes, among other things—(1) Use of ordinary AGGRESSIVE WEAPONS; (2) Use of actively DEFENSIVE WEAPONS, such as stings, stink-glands, &c.; (3) CO-OPERATION for defensive purposes between members of a community.

An attacked animal, however, may be unfitted to offer either active or passive defence, or may reserve its resistance, and in both these cases commonly endeavours to effect its escape. This may be considered under a third main heading, *i.e.*—

III. RETREAT

It is scarcely necessary to tabulate the various ways in which this is effected by different forms. Many animals are possessed of great running powers, others can burrow rapidly, and so on. The existence of dwellings or refuges is often a great help to retreat, which may also be assisted by various special devices.

It must, of course, be understood that there are no sharp lines of separation between animals which employ different modes of defence, for some species may fall under more than one heading, and even those which in the first instance attempt to retreat may nevertheless offer a determined resistance should they be overtaken by their foes, *e.g.* deer and poisonous snakes.

I. PRECAUTIONARY MEASURES

(1) BODILY CHARACTERISTICS.—

(*a*) Arrangements which bring about INCONSPICUOUSNESS. A particular kind of animal may be possessed of peculiarities of form or structure, or both, in virtue of which it harmonizes so well with the surroundings that detection by an enemy becomes a difficult matter. But to reap the full benefit of this a form so protected must remain perfectly motionless, as the least movement may at once destroy the illusion. And since movement is absolutely necessary to the great majority of animals, the protective

such as "precautionary measures" and "passive defence", the defence is of purely unconscious kind, and has been determined by evolutionary factors working irrespective of the will or knowledge of the animal. Even when an animal actively defends itself against attack it does not follow that it has any clear idea of what the aggressor is after, though it must be admitted that the latter has more clearly-cut ideas on the subject.

The following scheme will perhaps serve to illustrate the main principles of animal defence in the limited sense indicated above, and it will be followed by detailed description of illustrative instances, though space forbids anything like a complete review of the animal kingdom under each heading.

I. PRECAUTIONARY MEASURES

Under this heading will be grouped those various defensive measures which tend to obviate attack altogether, and these fall pretty naturally under (1) Bodily Characteristics, and (2) Mode of Life or Habits.

(1) Bodily Characteristics.—These may be considered in so far as they result in (*a*) Inconspicuousness, and (*b*) Conspicuousness. The first is obvious and the other will be clear after explanation.

(2) Mode of Life.—Defence may be promoted by (*a*) Feeding at favourable times, (*b*) Feeding in favourable places.

Supposing, however, that attacks are actually delivered, their intention may be frustrated by means falling under a second large heading.

II. RESISTANCE

This may take the form of either (A) Passive Defence, or else (B) Active Defence.

(A) Passive Defence.—This may be effected by (1) Bodily Characteristics, or by (2) Special Habits, and not infrequently both contribute to the efficiency of the resistance offered. There is also (3) Fecundity as a defensive measure.

(1) Bodily Characteristics.—Of these perhaps the most important are—(*a*) Unpalatableness and Indigestibility, resulting from various peculiarities; (*b*) Possession of

Armour, as purely defensive arrangements may be broadly termed.

(2) SPECIAL HABITS, such, *e.g.*, as the Death-feigning Instinct, Rolling-up Instinct, &c.

(3) FECUNDITY as a means of defending the species.

(B) ACTIVE DEFENCE.—This employs the method of counter-attack, and includes, among other things—(1) Use of ordinary AGGRESSIVE WEAPONS; (2) Use of actively DEFENSIVE WEAPONS, such as stings, stink-glands, &c.; (3) CO-OPERATION for defensive purposes between members of a community.

An attacked animal, however, may be unfitted to offer either active or passive defence, or may reserve its resistance, and in both these cases commonly endeavours to effect its escape. This may be considered under a third main heading, *i.e.*—

III. RETREAT

It is scarcely necessary to tabulate the various ways in which this is effected by different forms. Many animals are possessed of great running powers, others can burrow rapidly, and so on. The existence of dwellings or refuges is often a great help to retreat, which may also be assisted by various special devices.

It must, of course, be understood that there are no sharp lines of separation between animals which employ different modes of defence, for some species may fall under more than one heading, and even those which in the first instance attempt to retreat may nevertheless offer a determined resistance should they be overtaken by their foes, *e.g.* deer and poisonous snakes.

I. PRECAUTIONARY MEASURES

(1) BODILY CHARACTERISTICS.—

(*a*) Arrangements which bring about INCONSPICUOUSNESS. A particular kind of animal may be possessed of peculiarities of form or structure, or both, in virtue of which it harmonizes so well with the surroundings that detection by an enemy becomes a difficult matter. But to reap the full benefit of this a form so protected must remain perfectly motionless, as the least movement may at once destroy the illusion. And since movement is absolutely necessary to the great majority of animals, the protective

arrangements now to be described are much less effective than might at first sight be imagined. Aggressive animals would die out altogether if their prey gradually evolved into a perfectly protected condition, and such a state of things can never be realized. Suppose a species A to feed upon other species B, C, and D. Then as these develop characteristics which make them more and more difficult to detect, A will keep pace more or less with this by improvement of its sense organs and powers of observation. Besides which, it does not follow that a protected form which deceives the eye will necessarily deceive other senses, such, *e.g.*, as that of smell. This, however, is a matter which still requires working out, for most attention has so far been paid to arrangements which may metaphorically be called "optical illusions". And again, even if B, C, and D succeeded in evading the pressing attentions of A altogether, that species might be enabled to divert its energies in some other direction.

PROTECTIVE RESEMBLANCE (as arrangements tending to inconspicuousness may be called) may either be *general*, so as to harmonize with the colour scheme, illumination, &c., of the surroundings, or they may be *special*, so as to bring about an imitation of some particular object, as a twig or leaf. It will be convenient to consider these cases separately.

GENERAL PROTECTIVE RESEMBLANCE

TRANSPARENCY.—Vast numbers of marine animals belonging to many different groups are to be found either swimming or drifting in the surface layer of the sea, and it is characteristic of such forms that they should be of glass-like transparency, which obviously makes them very inconspicuous. Such an arrangement, of course, only partly meets the situation, for the internal organs of these "glass animals", to use the German expression, must of necessity be at least partially opaque, and many of them may be condensed as it were into a limited region of the body. But such organs, after all, look like bits of floating weed. Good examples are furnished by free-swimming Ascidians, such as Salps, many pelagic members of the Sea-Snail kind (Gastropods), especially those which are known as Sea-Butterflies (Pteropods) and Swimming-Snails (Heteropods), many Crustacea, numerous Worms, and above all creatures such as Jelly-Fish (Hydrozoa), together with the various species of Comb-Jellies

(Ctenophora). Transparency or translucency is a highly characteristic feature in hosts of the free-swimming young which belong to such groups as Molluscs, unsegmented and segmented Worms, Lamp-Shells, Moss-Polyps, Crustacea, and Echinoderms. A typical instance is that of the little Glass-Crabs which were originally believed to be distinct species, but are now known to be the larvæ of Rock-Lobsters (*Palinurus*) and related animals.

Snow Animals.—Another striking and well-known instance of general resemblance to surroundings is afforded by snow and ice animals, which by possession of white fur or feathers are rendered extremely inconspicuous. Mammals and Birds furnish a number of striking examples. It is a rare occurrence for an animal to be white all the year round, for this can only be expected to happen in very high latitudes, where the ground is permanently covered by snow and ice. The Polar Bear is an instance, but the colour in this case is almost entirely aggressive, enabling the animal to approach its prey without attracting observation.

Among birds the Snowy Owl (*Nyctea Scandiaca*) of the Arctic regions, but which sometimes wanders into more southern latitudes, as *e.g.*, North Scotland, is permanently coloured so as to harmonize with snowy surroundings. Its prevailing hue is white, but this may be flecked or barred with blackish-brown. Though in the main aggressive in purpose, the Owl is doubtless protected to some extent by its resemblance to the background against which it is usually seen in the far north.

Desert Animals.—Many animals which inhabit desert regions exhibit general protective resemblance to their surroundings, exemplifying in a practical manner the value of khaki tints where concealment is desirable. The colour is by no means always of uniform character, for there may be spots, flecks, or stripes, all being calculated to make assimilation with the surroundings more complete. Camels, Antelopes, Desert Foxes (fennecs), and Jerboas are good instances among the Mammals, while ancestral Horses were probably clad in striped khaki. Among birds may be mentioned Desert Larks, Desert Finches, and Sand-Grouse (fig. 474). Of the last, Brehm (in *From North Pole to Equator*) writes graphically as follows, in reference to the Sahara:—"Among the sparsely sprouting alfa there is a numerous flock of birds about the size of pigeons. Tripping hither and

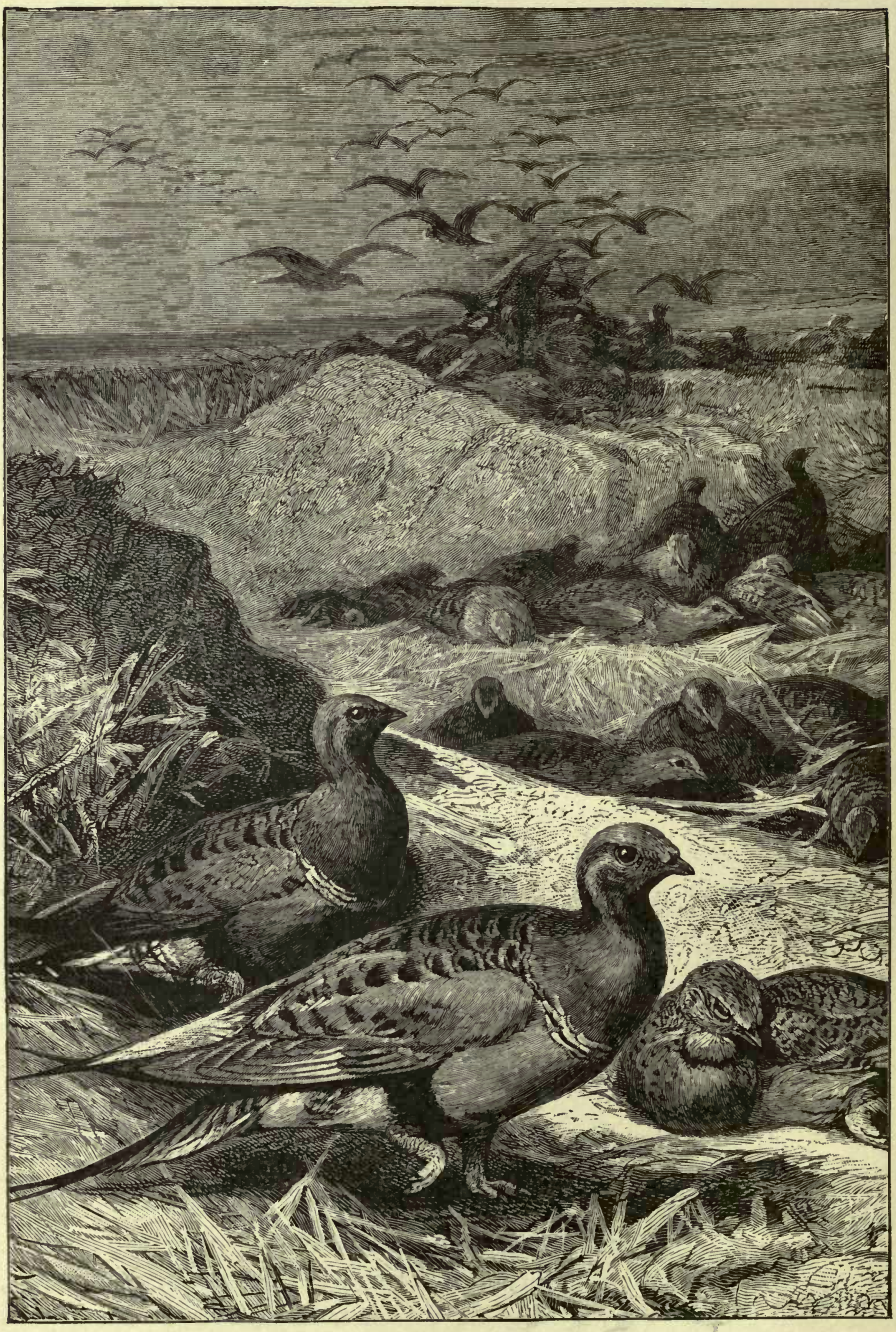


Fig. 474.—Pallas's Sand-Grouse (*Syrrhaptes paradoxus*), native to the steppes of Asia

thither, scratching and scraping with their bills, they seek for food. Without anxiety they allow the rider to approach within a distance of a hundred paces. A good field-glass enables one to see not only every movement, but also the more prominent colours of their plumage. With depressed head, retracted neck, and body held almost horizontally, they run about in search of seeds, the few grains which the desert grasses bear, freshly-unfolded panicles, and insects. Some stretch out their necks from time to time and peer circumspectly around; others, quite careless, paddle in the sand, preening their feathers, or lie at ease, half-sideways, in the sun. All this one can distinctly see, and one can count that there are over fifty, perhaps nearly a hundred. What sportsman would their presence not excite? Sure of his booty, the inexperienced traveller shuts up his field-glass, gets hold of his gun, and slowly approaches the gay company. But the birds disappear before his eyes. None has run or flown, yet none is to be seen. It seems as if the earth had swallowed them. The fact is, that, trusting to the likeness between their plumage and the ground, they have simply squatted. In a moment they have become stones and little heaps of sand. Ignorant of this, the sportsman rides in upon them, and is startled when they rise with simultaneous suddenness, and, loudly calling and scolding, take wing and fly noisily away. But if he should succeed in bringing one down, he will not fail to be struck by their colouring and marking, which is as remarkable as their behaviour. The sand-coloured upper surface, shading sometimes into gray, sometimes towards bright yellow, is broken and adorned by broad bands, narrower bars, delicate lines; by dots, spots, points, streaks, and blurs, so that one might fancy at first sight that birds so marked must be conspicuous from a distance. But all this colour-medley is simply the most precise colour of the ground; every dark and light spot, every little stone, every grain of sand seems to have its counterpart on the plumage. It is no wonder then that the earth can, as it were, make the bird part of itself, and secure its safety, which is further assured by the creature's strong wings, which are capable of incomparably swift flight."

A great many Lizards (see fig. 60) inhabit dry sandy places, and present dull coloration in accordance with their surroundings, as is the case with the common British Sand-Lizard (*Lacerta agilis*), while numerous species are to be found in desert regions.

Examples of these are the Thorn-tailed Lizards (*Uromastix*) of North Africa and South-west Asia, which are burrowing forms living entirely on plant-food, so that the coloration may be regarded as entirely protective, while in species which prey upon insects and other small animals it is aggressive as well. This is the case, for instance, with the Desert Monitor (*Varanus griseus*), which has pretty much the same range as the last-named species. It is a large animal, attaining a length of over 4 feet, and presents dark bars and streaks upon a neutral ground-colour. Quite similar as regards general hue and character of marking is the Common Skink (*Scincus officinalis*) of the Sahara, which, however, is only about 3 inches in length.

Our only poisonous British Snake, the Adder (*Pelias berus*) (see vol. i, p. 233), commonly found on sandy heaths, exhibits general resemblance to surroundings, which is both protective and aggressive, as in the case of the Sand-Lizard. The ground colour is usually brownish or greenish gray, and the back is ornamented with a dark zigzag stripe. There are many groups of true desert Snakes which are as inconspicuous as the Mammals and Birds which inhabit the same regions, and here, too, as in the Adder, the colouring serves a double purpose. A typical example is the Horned Viper (*Cerastes cornutus*), receiving its name from the presence of a pointed projection above either eye in the male, and less often in the female as well. It inhabits the deserts of North Africa and Arabia, and is of a sandy colour with numerous dull blotches.

Desert Insects also exhibit the dull neutral tints and blotchings or mottlings which prove so efficient in vertebrate forms. Examples are found in certain Desert Grasshoppers (*Xiphocera asina*, *Trachypetra bufo*, and *Methone Anderssoni*) native to South Africa.

Reversed Shading.—General protective resemblance is not merely a matter of appropriate colouring, but also of appropriate disposition of *light* and *shade*, and this is exemplified by many of the cases already described, as well as by others to which allusion will now be made. If such a curved white or brownish solid as a common hen's egg be placed on a table and strongly illuminated from above, it will be obvious that its upper part will present high lights, while its under side will be in shadow, the two regions gradually merging into one another. When a drawing of an egg is made on a piece of paper, the intention is

to produce an optical illusion, whereby the effect of a solid on the eye is simulated, and this is done by shading darkly the side opposite to the one from which the light is supposed to come. The exact opposite to this is brought about in nature as a protective device, and a solid object is made to appear more or less flat by dark colouring above shading into light coloration below, a very common state of things which has already been briefly referred to (p. 271). A very ingenious model, of which a copy exists in the Cambridge Museum of Zoology, has been devised to demonstrate this. The back of a rectangular box, of which the front and sides are glass, is marked with a tangle of blotches and streaks to represent the confused mixture of light and shade which may be seen in such a natural background as that presented by the sedges and other plants which line the margin of a pond. A little in front of this a rod is fixed from side to side, and to this are attached a couple of clay models representing conventionally the bodies of two birds, with the usual curved outlines. The upper parts of these are tinted like the background and blotched in a similar manner, and are gradually shaded off at the sides so as to pass insensibly into the unshaded whitish tint of the under parts of the models. It should further be stated that the rod can be rotated on its long axis by means of a handle so as to move the diagrammatic birds. Standing at a little distance from the model, before being acquainted with its purpose, an average observer will almost certainly fail to see the dummy birds, but they at once flash, as it were, into view when moved by means of the handle. The device clearly illustrates why in so many animals the upper surface is dark and the under surface light, and also shows that a protected form must remain motionless if it is to derive much benefit from its resemblance to surroundings. The principle is illustrated in nature by such Mammals as Hares and Rabbits, by almost any common sort of small Bird, by Lizards, Snakes, Frogs, and innumerable Fishes. The last case is of particular interest, for in such a form as, say, a Whiting, the distribution of colour results in inconspicuousness as seen in side view, while the darker upper side of the body is liable to be confounded (at least in shallow water) with the background presented by the sea-floor, and the pale under side is not particularly obvious when looked at from below. It is clear that floating or swimming

organisms thus derive an extra benefit from the lighter colour of the under side, as, of course, they are liable to be attacked from below, which is not usually the case with terrestrial forms. Besides fish, other interesting instances of this device may be taken from the larger pelagic forms which drift or swim at or near the surface. These, Wallace states (in *Darwinism*) ". . . are beautifully tinged with blue above, thus harmonizing with the colour of the sea as seen by hovering birds; while they are white below, and are thus invisible against the wave-foam and clouds as seen by enemies beneath the surface. Such are the tints of the beautiful nudibranchiate mollusc *Glaucus atlanticus*, and many others."

Flat-Fishes.—It has just been shown that compact, curved forms are often made to appear flattish by a particular distribution of colour and shading, but it is clear that similar advantages might be secured in an entirely different manner, *i.e.* by the body actually becoming flat. A striking case of this is that afforded by the Flat-Fishes, such as Sole, Turbot, Plaice, and the rest. These, when in the condition of young fry, swim about like ordinary fishes, and possess the same bilateral symmetry. Very soon, however, they become laterally flattened, and take to living on the sea-floor, with either the left or right side downwards, according to the species. This side remains white or pale, though not for the reason given in the case of animals with pale ventral surfaces, and its eye migrates to the side which is kept upwards; otherwise it would be of no use. And, further, the upwardly-directed surface becomes darkly pigmented so as to harmonize with the sand or mud upon which the animal lives, the resemblance often being enhanced, much as in desert animals, by the presence of spots and blotches of darker or different tint. Here, however, as in so many other cases, protection is only afforded by the coloration and marking when the animal remains at rest. As in the case of the model already described (p. 283), movement at once destroys the illusion, and in the case of a flat-fish the attention of other animals must be attracted by the display, to a greater or less extent, of the white or light-coloured side. The fish would be much better protected if both sides were dark, but the development of pigment in the skin is bound up with the action of light, which is largely excluded from that side of the body which faces habitually downwards.

Specialized General Resemblance.—The animals so far mentioned harmonize generally with the background against which they are seen, but other instances are known where the form and coloration are such as to make the creature appear part and parcel of some special object upon which it lives. Such are some cases which have been described of association between certain Corals and Sea-Snails. There is, for example, a North American Coral (*Leptogorgia virgulata*) which in shallow water is of an orange-yellow colour, but of deep-reddish tint in deeper water, the position of the individuals making up the colony being marked by white spots. A Sea-Snail (*Ovulum uniplicatum*) lives upon the branches of this Coral, with which it harmonizes precisely in colour, being orange-coloured in one case, red with white spots in the other. Curiously enough, a similar close relation has been noticed between a Coral and a Sea-Snail (*Gorgonia verrucosa* and *Ovulum patulum*) which live in British seas, both animals being red in colour. The Snail in this latter case (and no doubt in the other as well) is doubly benefited, for the Coral is distasteful to fish, and the Snail consequently has a good chance of escaping the dangers of a too close inspection. Large specimens are often to be seen in museums of a Coral (*Gorgonia*) which protects Brittle-Stars in much the same way, these holding on to the Coral by twining the tips of their slender arms round its branches. A similar association is recorded between a rose-coloured Australian Sponge and a small species of Sea-Slug. Sponges, it may be noted, are notoriously inedible, which is, of course, an additional benefit to the mollusc.

General Resemblance in Eggs and Young.—The harmonizing by means of form and colour with the usual surroundings, to which the name of General Protective Resemblance has been given, is by no means confined to adult forms, for it is exemplified by various earlier stages in existence. These have perhaps been more fully worked out in Birds and Insects than in other groups, and one or two examples taken from these must suffice. Birds' eggs, when laid in concealed places, free from observation, are commonly white, but when exposed to view are more or less coloured or marked, or it may be both. And the plumage of such fledglings as run about on the ground is usually speckled or mottled to harmonize with the surroundings, which renders them extremely difficult to see, especially if the little creatures crouch

close to the ground and remain motionless on the first note of danger, as is commonly the case. Admirable instances of the kind are afforded by the Ringed Plover (*Ægialitis hiaticula*) and Kentish Plover (*Æ. Cantiana*), both of which lay grey eggs with dark markings among shingle on the sea-shore. In these and their allies eggs and young alike are exceedingly difficult to detect (figs. 475, 476). Inspection of an admirable series of eggs and nests with natural surroundings displayed in the British Museum (Natural History) at South Kensington will reward anyone inclined to take an interest in the matter. An apparent exception to the rule is afforded by the eggs of Wood-Pigeons, which, although exposed to observation, are white in hue. But it has been pointed out that these are liable to be seen from *below* through the chinks in the nest, which may be compared to a piece of open basket-work, and are therefore seen against the bright background of the sky. We are reminded here of the light under-surfaces of marine animals, which harmonize with a similar background (p. 283).

Fig. 475.—Eggs of Ringed Plover (*Ægialitis hiaticula*)

Fig. 476.—Crouching young of Peewit (*Vanellus cristatus*)

Turning from Birds to Insects, we find innumerable instances of all the different stages in the life-history being rendered inconspicuous by coloration and markings which blend with the immediate surroundings. Speaking of a native moth, Poulton (in his delightful book on *The Colours of Animals*, from which a number of the illustrations in this part of the subject are taken)

remarks:—"The caterpillar, chrysalis, and moth of the Black Arches (*Psilura monacha*) are beautifully protected in this way. The black pupa is fixed in a chink in the bark by a few inconspicuous threads; its dark colour harmonizes with the shadow in the chink, while the long tufts of greyish hair project and exactly resemble the appearance of lichen. Both larva and moth are coloured so as to resemble common appearances presented by

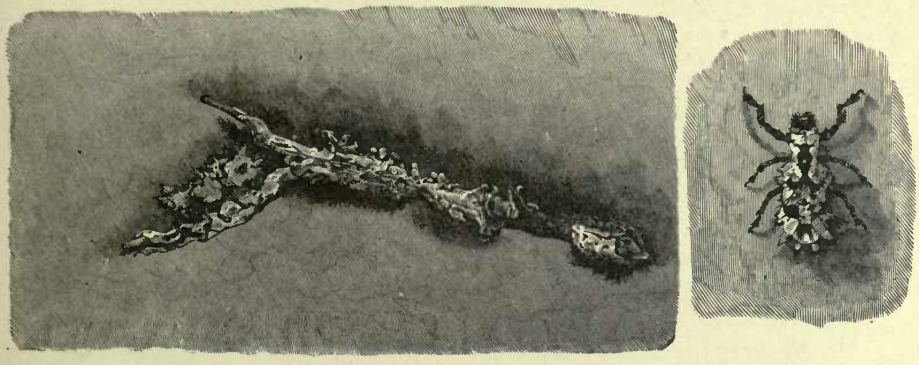


Fig. 477.—A Beetle (*Lithinus nigrocristatus*) which resembles Lichen

lichens, and both habitually rest on lichen-covered bark." Some beetles exemplify the same device (fig. 477).

Masking.—General protective resemblance to surroundings is effected in a number of animals belonging to widely-different groups by the presence on the surface of their bodies of plant-growths or various foreign substances. Some small West Indian Land-Snails, for instance, escape observation by reason of the dirt with which their shells are covered, but among molluscs a much more remarkable case is that of certain Sea-Snails (species of *Xenophorus*) (fig. 478). Speaking of one of these, Chun (in *Aus den Tiefen des Weltmeeres*) describes it as "a snail which possesses the remarkable habit of cementing to its shell in a symmetrical manner the empty shells of other snails. It might almost be imagined that an artistic hand took part in grouping these foreign shells." Bits of coral and stone may also be included.

Even more remarkable devices are adopted by some of the Crustacea. There are, for example, various kinds of Spider-Crab (species of *Maia*, *Inachus*, *Stenorhynchus*, &c.) in which the body is covered with a thick growth of sea-weed, and it has been shown by Bateson and others that this is not an accident, for these

creatures voluntarily convert the surfaces of their bodies into a kind of sea-weed garden. "The Crab takes a piece of weed in his two chelæ, and, neither snatching nor biting it, deliberately tears it across, as a man tears paper with his hands. He then

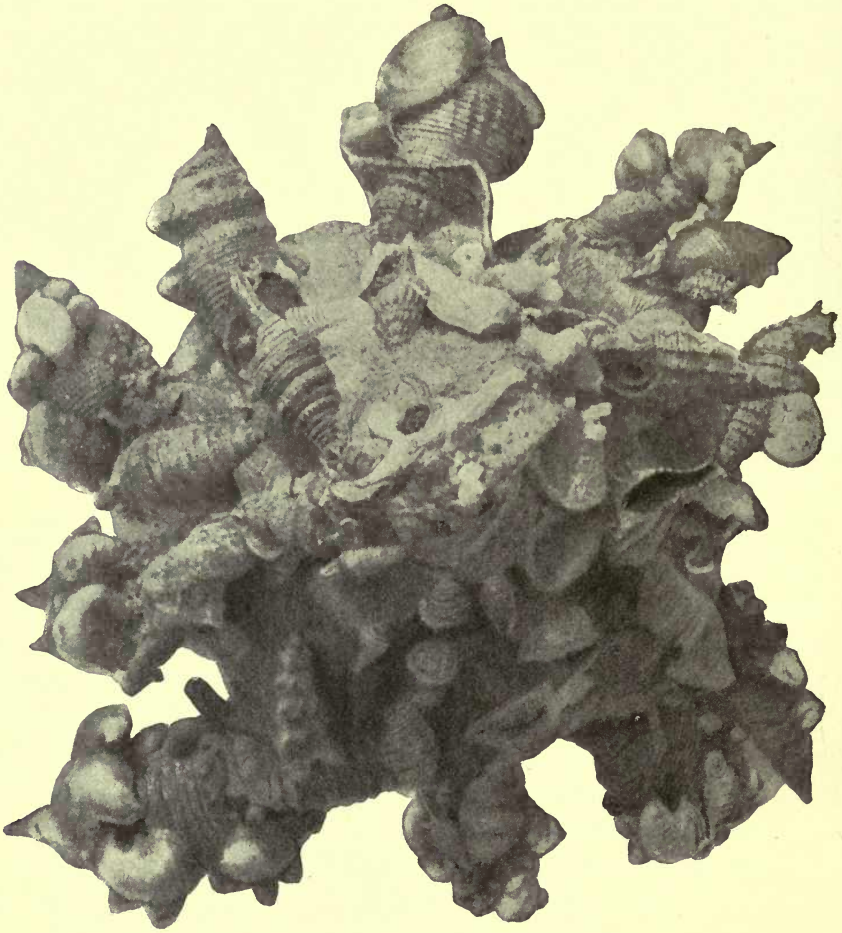


Fig. 478.—Upper side of a Xenophorus Shell

puts one end of it into his mouth, and after chewing it up, presumably to soften it, takes it out in the chelæ and rubs it firmly on his head or legs until it is caught by the peculiar curved hairs which cover them. If the piece of weed is not caught by the hairs, the Crab puts it back in his mouth and chews it up again. The whole proceeding is most human and purposeful. Many substances, as hydroids, sponges, Polyzoa, and weeds of many kinds and colours, are thus used, but these various substances

are nearly always placed symmetrically on corresponding parts of the body, and particularly long, plume-like pieces are fixed on the head, sticking up from it" (Bateson).

Some Sea-Urchins render themselves very inconspicuous by heaping bits of stone and shell upon their bodies. One would be inclined to think their firm spiny shell quite enough by way of protection, but it does not keep off star-fishes.

The last example of masking to be noted here is that of a large red Sea-Anemone (*Tealia crassicornis*) which abounds on our coast. The body of this creature is covered by sticky knobs, to which small pieces of stone adhere. When uncovered by the tide the animal draws in its tentacles and shrinks into a rounded lump, which, in virtue of its extraneous covering, looks like a little heap of gravel, and is commonly overlooked by those unaware of the facts of the case.

VARIABLE GENERAL RESEMBLANCE

The examples of protective resemblance so far quoted are mostly permanent adaptations to one particular sort of surrounding. There are, however, numerous animals which possess the power of adjusting their colour more or less rapidly so as to harmonize with a changing environment.

Colour-Change in Snow-Animals.—Some of the best-known of these cases are found among those Mammals and Birds which inhabit countries more or less covered with snow during a part of the year. A good instance is afforded by the Irish or Variable Hare (*Lepus variabilis*), which in these islands is chiefly found in Ireland and Scotland. In summer this looks very much like an ordinary Hare, though rather greyer in tint and smaller in size, but in winter it becomes white, with the exception of the black tips to the ears. Investigations which have been made on the closely-allied American Hare (*Lepus Americanus*) seem to show that the phenomenon is partly due to the growth of new hairs of white hue, and partly to a change in colour which affects the tips of the ordinary hairs. In both cases the whiteness would appear to be the result of the presence of minute bubbles of carbonic acid gas in the substance of the hairs themselves, they absorbing the gas from their roots, where it would appear to be generated. The Common Stoat (*Putorius ermineus*) (see figs. 315 and 316) is subject to similar colour-change in the northern parts of its range.

In summer it is of a bright reddish-brown colour, with the exception of the under parts, which are yellowish-white, and the end of the tail, which is black. But in winter the entire coat, save only the tip of the tail, becomes white, and in that condition the animal is known as an Ermine. A similar example is afforded by the Weasel (*Mustela vulgaris*). The seasonal change in the vegetarian Irish Hare is purely of protective character, but in such an actively carnivorous creature as a Stoat or Weasel it is aggressive as well, rendering the animal inconspicuous to its prey.

Among Birds no better example can be selected than the Ptarmigan (*Lagopus mutus*) (fig. 479), native to the Scottish

Fig. 479.—Ptarmigan (*Lagopus mutus*), in winter plumage

Highlands among other places. The summer plumage of this bird is brown with darker markings, but in winter it is pure white, except that the outer tail-feathers remain black, and the male bird retains a black band in front of the eye.

Colour-Change in Chameleons.—The power of adjusting its colour to suit the surroundings in the Chameleon is almost proverbial, and the change here takes place with extreme rapidity. As in the Stoat, it is quite as much aggressive as protective in nature. The colour-change in this case is brought about by alterations in the size of pigment-holding cells contained in the deeper part of the skin. Under the influence of the nervous system these can either be contracted to mere spots, or relaxed into branching star-like forms. Since they are arranged in a number of layers and contain different sorts of pigment, it is

clear that the colour effect will vary according to the number which are at a given time in a relaxed condition, and the depth in the skin at which these are situated. And it has further been proved that the eyes of the animal must be uninjured if the hues of the body are to be adjusted, so that the colours of the surroundings first affect the visual organs, from which nervous impulses are carried to the brain and thence in a roundabout way to the skin. It will readily be perceived that a case like this presents a physiological problem of no little complexity, the nature of which has only been indicated. It may be here remarked that though the Chameleon is the most striking example among the Reptiles of colour-change, it is by no means the sole member of that class which illustrates the phenomenon.

Colour-Change in Amphibians.—Some familiar Amphibians vary in colour according to the surroundings, though not so rapidly as the last-named animal, and the nature and causes of the change are substantially the same. Our Common Frog (*Rana temporaria*) has been the subject of careful investigations in this respect. It is quite easy to produce the change in a captive specimen. If placed for a short time in a dark box it will assume a blackish appearance, and if then transferred to fresh damp grass and placed in a bright place it will speedily take on a yellowish-green tint. The arrangement is obviously protective, but it may be aggressive as well, for insects form a large part of the food, and a good dinner may depend upon approaching them unobserved until the long tongue can be shot out with a good chance of catching them (see p. 82).

Colour-Change in Fishes.—Fishes, especially those which are ground-feeders, possess in many if not all cases a power of colour-adjustment, the mechanism being the same as in Reptiles and Amphibia. The protective arrangements in Flat-Fishes have already been noted (p. 284), but probably the description might have been given with greater propriety under the present heading. Plaice, for example, are known to be able to vary their prevailing hue according as the surrounding part of the sea-bottom is light or dark, and a very interesting observation was made many years ago upon a number of these fishes which at the time were resting upon white sand. With the exception of one specimen they had all assumed a light colour, and on closer examination that particular fish proved to be blind, and therefore did not possess the

power of colour-adjustment. Similar observations have been made in the case of Trout. Many other fishes are well known to vary in hue according to their surroundings, and the present writer remembers seeing a striking case some years ago in a marine form known as the Lumpsucker (*Cyclopterus lumpus*). This fish is a ground-feeder, and an example had been caught at the floating marine station then existing at Granton, near Edinburgh. It was of a forbidding black appearance, and to keep it alive for further observation was suspended in the clear sea-water within a sort of drum made of net-work, the top of this being just above the surface. After a short time the fish was pulled up for re-examination, and was then found to be of a bright-green colour, strikingly different from its former sooty hue, and harmonizing well with the sea-water.

It has been proved for Frog and Chameleon, and is no doubt true for fishes as well, that the colour-changes are brought about by various external agents which affect the nervous system, these including not only light but also changes in temperature, contact with surrounding objects, and variations in the amount of oxygen available for breathing.

Colour-Change in Molluscs.—Some of the Sea-Slugs exemplify variable protective resemblance. This is the case, for example, with *Elysia viridis*, a little creature closely resembling a Land-Slug in form and method of progression. Those specimens found among green sea-weeds are green in colour, while brown weeds of various hue harbour individuals which harmonize with their particular tint. (See as to what has been said on p. 285 regarding *Ovulum*.)

Colour-Change in Crustaceans.—Many of the smaller Crustaceans which are translucent, or it may be transparent, afford most instructive examples of variable protective resemblance. The Common Prawn (*Palæmon serratus*), for example, has long been known to become dark in colour when placed on a dark surface, and colourless when allowed to rest on a white surface, but by far the most remarkable case so far investigated is that of the Æsop Prawn (*Hippolyte varians*), a species which is common in low-tide pools and shallow water. This has been the subject of an elaborate research by Keeble and Gamble, who have confirmed and extended the results of several previous workers. It is found that these Prawns harmonize in the most

perfect manner with the weeds among which they happen to be found, green, red, or brown as the case may be; and further, that individuals adapted to live among weed of one colour are able to adjust their appearance, though not very rapidly, to surroundings of new form and colour. There is further a quick response to alterations in the intensity of light. But beyond this there is a remarkable *periodic colour-change*, corresponding to the alternations of day and night, the utility of which is not at present known. To quote the above-named authors:—"Every evening, as darkness comes on, Hippolyte gradually loses its distinctive diurnal colour. In summer the change begins at about 9 P.M., in winter at about 5 P.M. Towards this or that time, according to the season, a reddish tint—a sunset glow—the foreshadowing of the change, makes its appearance. This is followed by a green tinge which spreads fore and aft from the middle of the body. The green colour gradually melts into blue, and a general increase of transparency sets in. Thus, as darkness falls, Hippolyte is seen to become of a wonderful azure-blue colour and absolutely transparent, except in the region of the liver and stomach, which are now very clearly visible. The depth of the blue colour varies in different specimens; in some it is almost indigo, in others the faint azure of a sky at sunset." The changes in hue depend upon the condition of branching colour-bodies which are present. These contain various pigments, the distribution of which can be varied as the result of the action of light and other agents, that work in part through the agency of the eyes and nervous system, and in part independently of these.

Colour-Change in Insects.—The subject of variable protective resemblance must be concluded by referring to some extremely interesting cases presented by Insects in the various stages of their life-history. Numerous instances are known where caterpillars of the same kind vary in colour according to the hues of their surroundings. This may be illustrated by an experiment of Poulton's conducted on the larvæ of the Peppered Moth (*Amphidasis betularia*). A large batch of eggs taken from the same individual was divided into two parts, one half being then hatched out among the green leaves and shoots of birch, and the other among dark-brown twigs of the same plant with a certain admixture of leaves. All the caterpillars of the former half were bright-green, while the large majority of the other

half were dark-brown, though about one or two per cent took their colour from the leaves present. Adaptability to surroundings as regards appearance is exemplified not only by caterpillars but also by the chrysalides of some moths and butterflies. No better example could be selected than the Small Tortoise-shell Butterfly (*Vanessa urticæ*), upon which Poulton conducted a remarkable series of experiments. By varying the surroundings at the time when the caterpillars become quiescent preparatory to passing into the motionless pupa-stage, he was able to produce at pleasure dark, light, and gold-coloured chrysalides. The utility of a gilded appearance is not at first sight obvious, but it may be pointed out that it would harmonize with a rock-surface which presented such glittering minerals as mica (flakes of which are used on Christmas trees and the like to give the glistening appearance of snow). Rock-surfaces in our damp climate are generally dull, except when freshly fractured, but in hotter and drier countries they often present a glittering appearance, and in this connection it is interesting to note that the word *chrysalis*, which means golden (Gk. *chrysos*, golden), is taken from Aristotle, and was no doubt given from the appearance of certain pupæ noticed by the ancient Greeks. Possibly, therefore, the power of producing gilded chrysalides possessed by the caterpillars under discussion may be reminiscent of a time when the ancestors of the Small Tortoise-shell Butterfly inhabited more southern latitudes than ours. The range of this particular species at the present time includes a good deal of the northern hemisphere, and the distribution of the family to which it belongs (Nymphalidæ) is world-wide, so that there is nothing improbable about the suggestion.

SPECIAL PROTECTIVE RESEMBLANCE

Here are included cases where inconspicuousness results from resemblance to some special inedible object, instead of being due to properties of form and colour whereby harmony with the general surroundings is brought about. There is, however, no sharp boundary-line between these cases; *e.g.* a brown Æsop Prawn may not only assimilate generally to the appearance of the weed to which it clings, but may also simulate a special part of this. Special Protective Resemblance, like the other form of assimilation, may be either constant or variable.

Constant Special Protective Resemblance.—A good instance on the border line between general and special resemblance is afforded by some of the Sloths, which hang head downwards from the branches of trees in South American forests. The harsh greenish-looking fur of these creatures harmonizes very completely with the moss and lichen by which they are commonly surrounded, and it is very interesting to note that the hairs are grooved or fluted in a peculiar way so as to afford a lodgment to a microscopic green plant (alga) which, favoured by the humidity of the air, is able to grow upon them. But, in addition to this arrangement promoting general resemblance, there is another bringing about special resemblance, in the form of a round fawn-coloured patch between the shoulders, and this is the more conspicuous because it has a dark margin. The effect is similar to that produced by a rotten branch which has broken off short, leaving a stump with a light centre constituted by the wood, and a dark margin due to the fractured bark.

Another instance among Mammals which may more properly be referred to special resemblance is afforded by the Pangolin (*Manis*), a scaly arboreal Edentate native to East Africa and Southern Asia. If alarmed when climbing a tree-trunk, this animal lets go with its fore-limbs, and, supporting itself by hind-limbs and tail, presents an appearance quite comparable to a broken branch.

Among Birds, the Coot, Moor-Hen, and Grebes may possibly be taken, though the matter is not beyond cavil, as illustrations of some particular part being shaped so as to confer special protective resemblance. The toes of these birds are broadened out in a very curious manner, and it has been suggested that this gives them a certain resemblance to the leaves of floating water-plants, whereby rapacious fishes are deceived and refrain from nibbling at them. Too much stress must not be laid on this, however, as it may be merely a case of broadening for the purpose of increased efficiency in swimming. Or possibly two ends may be gained at the same time.

There are also cases of young birds, belonging to species in which the eggs are laid and hatched out in exposed situations, where the colour and markings not only harmonize generally with the surroundings, but also bring about a protective resemblance to a single stone when the crouching attitude is assumed

on a sudden alarm. This is the case, for instance, with the young of some Plovers (see p. 286).

A good instance of special protective resemblance among the lower Vertebrates is afforded by Australian species (*Phyllopteryx eques*, and two others) of the curious fishes known as Sea-Horses, of which a less remarkable genus (*Hippocampus*) is commonly represented in museums. These Australian forms, which may be as much as a foot long, are laterally flattened, and attach themselves by means of their curly tails to pieces of

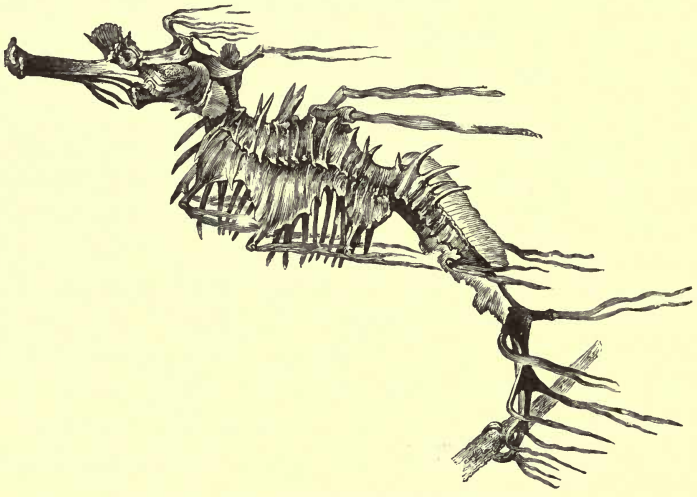


Fig. 480.—Australian Sea-Horse (*Phyllopteryx eques*)

brown sea-weed (species of *Fucus*). Günther (in *The Study of Fishes*) says of them:—"Not only their colour closely assimilates to that of the particular kind of sea-weed which they frequent, but the appendages of their spines seem to be merely part of the fucus to which they are attached". (Fig. 480.)

Herdman and others have described a number of very interesting cases of protective form and colour among Sea-Slugs. Some of these (notably *Doto coronata* and *Dendronotus arborescens*) have their upper surfaces richly studded with brightly-coloured projections (cerata), which at first sight serve to make them conspicuous, but in reality so closely resemble the branching colonies of zoophytes among which they live as to make them difficult for their enemies to detect.

Many of the most striking of the special protective resemblances so far described are to be found among Insects in various

stages of their existence. Among our native Moths, for instance, there is one group (*Geometers*) containing over 200 species, in which the succulent caterpillars move along in a curious way which has earned for them the name of Loopers, and is also the origin of the name of the group. The front part of the body bears three pairs of jointed legs corresponding to those of the future moth, while at the hinder-end are two pairs of sucker-like pro-legs. It is by alternate use of these fore and aft groups of limbs that the characteristic movements are effected. But the larvæ in question have also earned the name of Stick-Caterpillars, from the very perfect way in which they simulate resemblance to the twigs of plants on which they live. Holding on firmly by means of its pro-legs, and extending the body obliquely outwards, such a caterpillar remains motionless and rigid for hours, until the cravings of hunger render it necessary to crawl away and take the next meal. Such a severe trial of patience and muscular power are rendered rather less trying by a silken thread attaching the head to a neighbouring twig. A Stick-Caterpillar in the motionless condition harmonizes so perfectly with its surroundings, both as regards shape and colour, that it can only be detected by an unusually keen or practised observer. Poulton (in *The Colours of Animals*) describes as follows one of the most remarkable cases:—"I will illustrate the extraordinary degree of resemblance attained in *Geometræ* by a description of the larva of one of our most abundant species, the Brimstone Moth (*Rumia cratægata*). The appearance of the larva when seated among the twigs of its commonest food-plant—hawthorn—is shown in fig. 481. It will be observed that some of the twigs are slightly bent in the middle, and that

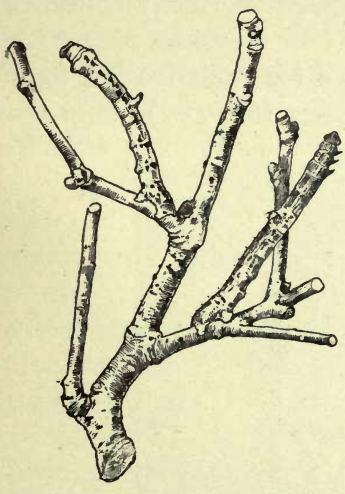


Fig. 481.—Caterpillars of Brimstone Moth (*Rumia cratægata*), in protective attitudes

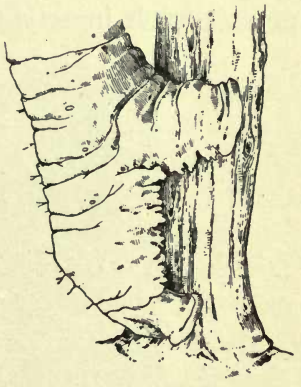


Fig. 482.—Hinder End of Caterpillar of Brimstone Moth (magnified)

a projection is placed on the angle; these appearances are exactly reproduced in the larva. The hind part of the larva is represented in fig. 482 (magnified 4·5 diameters), showing the claspers and the fleshy projections which occupy the furrow between the larva and the stem. The harmony of colour is quite as perfect as the resemblance of shape. The smaller branches of the hawthorn are partially covered by a thin superficial layer of a bluish-grey colour (the cuticle), while the deeper layers beneath are brown or green, or mixed brown and green; these tints become visible over a large part of the surface, owing to the breaking away of the thin layer. Hence the colour of the branches is brown or green, mottled with grey, and not only are these the exact tints of the larva, but the way in which the colours are blended is precisely similar in the animal and the plant. The marvellous fidelity with which the details are thus reproduced probably implies that the relation between the larva and this species of food-plant is extremely ancient. . . . This caterpillar can also adjust its colour to that of its individual surroundings, so that it would become greenish if it passed its life among young green shoots, and brown if it lived upon the older twigs. It is altogether one of the most perfectly-concealed forms in existence."

No less remarkable cases of protective resemblance are found among adult insects, one of the most perfect (fig. 483) being that

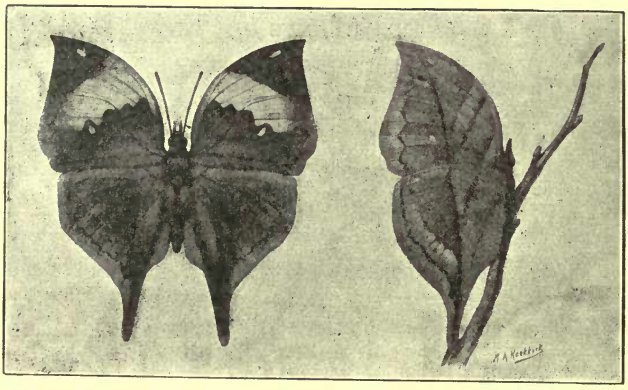


Fig. 483.—Indian Leaf Butterfly (*Kallima inachis*) with wings extended, and on twig in protective attitude

presented by certain Oriental and African Leaf-Butterflies (species of *Kallima*) described by Wallace. When on the wing these insects are conspicuous objects, owing to the bright orange and

purple tints which adorn the upper sides of their wings. Observers who have watched them in the dry forests which they haunt, call attention to their rapid flight, and the sudden way in which they settle on twigs and in the twinkling of an eye transform themselves into the semblance of withered leaves. In this resting attitude the wings are folded together so as to conceal the bright colours and expose their under sides, which in both colour and markings harmonize in the minutest details with the objects they resemble, even to the presence of spots comparable to diseased patches. On each fore-wing two small round areas are devoid of scales, leaving the transparent membrane quite bare, and when these two spots are applied to their fellows an appearance is brought about comparable to a hole, such as might be produced in a leaf by the attack of an insect larva. Antennæ, head, and body are hidden between the folded wings, which offer a continuous outline just like that of one of the neighbouring dead leaves, the fore-wings being pointed in front, and the hind-wings backwardly produced into narrow tails which pass muster as a leaf-stalk. The legs of the Butterfly are so slender as not to destroy the illusion.

Many of our native moths are so coloured and marked as to be readily mistaken for dead leaves, and one kind, the Buff-tip Moth (*Pygæra bucephala*), is, when at rest, a very perfect counterpart of a bit of rotten stick which has snapped across so as to give a flattish yellowish-brown surface at the end.

The Stick- and Leaf-Insects of the Locust and Grasshopper order (Orthoptera) closely resemble the objects after which they are named. Sharp (in *The Cambridge Natural History*) remarks of the latter:—"The resemblance presented by different kinds of Orthoptera to leaves is so remarkable that it has attracted attention even in countries where Natural History is almost totally neglected; in many such places the inhabitants are firmly convinced that the Insects are truly transformed leaves, by which they understand a bud developing into a leaf and subsequently becoming a walking-leaf or Insect. To them the change is a kind of metamorphosis of habit; it grew as a leaf and then took to walking."

Spiders also, in a number of cases, closely resemble special objects, the end being in this case aggression as well as protection. There is, for instance, a Mascarene species (*Cærostris*

mitralis) which when at rest might readily be mistaken for a projecting knot, while other sorts have been described in which splashes of birds' excrement are faithfully copied.

The foregoing examples will perhaps suffice to illustrate protective resemblance more or less constant in kind to special objects, and a few instances will now be given of the somewhat rarer phenomenon of variable resemblance of the same kind.

Variable Special Protective Resemblance.—So far as the species is concerned, the Leaf-Butterflies (*Kallima*) already described might very well be placed here, for there is great variability in the colouring of individuals, just as there is among the dead leaves to which the colours give resemblance. But cases are also known where the same individual is capable of altering its appearance so as to copy, as it were, more than one sort of external object. The power of doing this is suspected in far more numerous instances than those for which it has actually been proved, but Poulton (in *The Colours of Animals*) gives a striking and unequivocal example in the stick-caterpillar, which is the larval stage of the Early Thorn Moth (*Selenia illunaria*), a native species. When resting on a brown twig this caterpillar conceals itself in the way already described for a similar form, but when feeding upon a green leaf that method would be impossible. Yet by throwing its body into several sharp kinks, and remaining motionless, it assumes a resemblance to a shrivelled bit of dead leaf or some other object such as might be expected to occur on the foliage.

We have now discussed at some length cases of precautionary measures (see p. 276) depending upon bodily characteristics which make for inconspicuousness, and we must now turn to instances of precisely opposite kind, where bodily characteristics make their possessor very conspicuous.

CHAPTER XXVI

ANIMAL DEFENCES—BODILY CHARACTERISTICS PRODUCING CONSPICUOUSNESS

CONSPICUOUSNESS AS A MEANS OF WARDING OFF ATTACKS.—Numerous animals are possessed of stings, poison-glands, stink-glands, and the like, which are capable of making them disagreeable or dangerous to their enemies, and many such creatures are practically inedible. But as at close quarters they might be killed, even if not eaten, a device for advertising noxious qualities has been evolved in the form of what is known as WARNING COLORATION, to which are closely allied certain other warning methods independent of colour-effects. No doubt a considerable number of these conspicuous forms must fall victims to the attacks of inexperienced aggressors, who, however, taught by experience, are not likely to continue their investigations, so that the warning species is on the whole benefited. And the welfare of the individual is always subordinate to that of the species.

Warning devices carry in their train a very extraordinary phenomenon, for many perfectly harmless and edible kinds of animal trade upon the evil reputation, so to speak, of warning noxious forms, by coming to resemble these in a very detailed manner. This is technically known as PROTECTIVE MIMICRY, though of course the imitation is a purely unconscious one. Mimicking forms enjoy considerable immunity from attack, by means of sailing under false colours. It will be most convenient to consider the phenomena involved by warning under two separate headings: GENUINE WARNING and SPURIOUS WARNING (Mimicry).

GENUINE WARNING

The best-known cases of such warning are found among lower forms, but one typical case within the class of Mammals is known in the person of the American Skunk (*Mephitis suffocans*) (fig. 484), a creature that possesses glands the secretion of which

exhales a most disgusting and penetrating odour. In colour it is black and white, so distributed as to make it extremely conspicuous, for the *upper* side is white instead of the lower, as in

Fig. 484.—American Skunk (*Mephitis suffocans*)

cases where inconspicuousness is the end to be attained (see p. 282). The possession of a large bushy white tail, which is carried erect, makes the animal still more easy to see, and it is in the habit of progressing at an easy pace, which it does not quicken even when attack is threatened. Should these danger-signals be ignored by an inexperienced enemy, the Skunk defends

itself very effectively by ejection of the noxious fluid already mentioned, and of which Hudson says (in *The Naturalist in La Plata*):—"Men have been blinded for ever by a discharge of the fiery liquid full in their faces. On a mucous membrane it burns like sulphuric acid, say the unfortunates who have had the experience." The same author quotes from the *Ibis* a description given by Mr. Ernest Gibson of an encounter between an eagle-vulture (*Polyborus tharus*) and a skunk. "Riding home one afternoon he spied a skunk 'shuffling along in the erratic manner usual to that odoriferous quadruped'; following it at a very short distance was an eagle-vulture, evidently bent on mischief. Every time the bird came near, the bushy tail rose menacingly; then the caranco would fall behind, and, after a few moments' hesitation, follow on again. At length, growing bolder, it sprung forward, seizing the threatening tail with its claw, but immediately after 'began staggering about with dishevelled plumage, tearful eyes, and a profoundly woebegone expression on its vulture face.' The skunk, after turning and regarding its victim with an I-told-you-so look for a few moments, trotted unconcernedly off."

A number of Poisonous Snakes exemplify warning by colour or other means, and the reason for this is not immediately obvious, for these creatures possess very efficient defensive weapons in their fangs. But, as Poulton points out (in *The Colours of Animals*), snake-poison does not kill immediately, and the aggressor would have time to despatch his quarry before succumbing to it. Besides which, the amount of this poison available for the time being is but small, and a snake which has used its fangs is thereby left for some time in a comparatively helpless condition.

The Coral-Snakes of Asia, Africa, America, and Australia are among the best examples of Reptiles exhibiting warning coloration. One of the most striking species (*Elaps corallinus*), native to South America and the West Indies, is of a bright-red colour, marked with broad black rings, the margins of which are greenish-white.

Some snakes employ *terrifying* or *warning attitudes* as a means of warding off attack, notably the Cobras, which, when threatened, raise the front part of the body from the ground and inflate the neck, on the back of which is a prominent spectacle-like marking. The Puff-Adders of Africa swell up their bodies

under similar circumstances, and this possibly prevents other animals from assaulting them.

Many poisonous serpents are accredited with producing *terrifying* or *warning sounds*, which may or may not be associated with the other warning methods above described. The characteristic *hissing* is probably a case in point, and very probably the *rattle* of the protectively-coloured Rattlesnake may answer the same purpose (fig. 485).

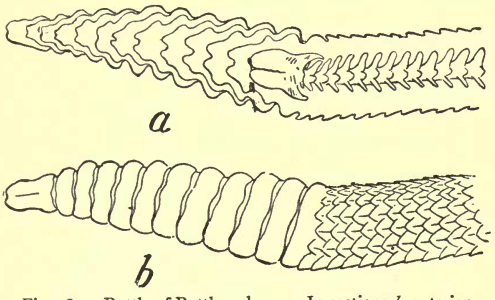


Fig. 485.—Rattle of Rattlesnake. *a*, In section; *b*, exterior

It is well known that the skin of Amphibians is provided with numerous small glands of which the secretion is more or less poisonous, and the common Toad, for example, is on this account treated with a fair amount of respect by Dogs, Cats, and the like.

There are certain species of Amphibia where these poisonous properties are advertised by the presence of *warning colours*. The conspicuous black-and-orange hues of the Spotted Salamander (*Salamandra maculosa*) may be of this nature, though a clearer case is afforded by a small red-and-blue frog described by Belt (in *A Naturalist in Nicaragua*). The observer mentioned, suspecting from its bold demeanour and glaring colours that this species was inedible, found by experiment that it was invariably rejected by fowls and ducks. A still more interesting case has recently been described by Annandale (in *The Proceedings of the Zoological Society of London, 1900*) of an Amphibian which only shows bright colours when alarmed. This is a species of Toad (*Callula pulchra*) "which is found not uncommonly in the Siamese States, among the rubbish which collects under the houses and in like situations. In this species, the upper surface of which is otherwise of a warm brown colour, a broad yellowish stripe runs along either side of the back; but the peculiar looseness of the skin and the folds into which it naturally falls prevent this stripe from becoming conspicuous. When the animal is disturbed, however, it draws air into its lungs until its body becomes almost globular, and the skin is stretched in such a way that its contrasting colours are displayed to their best advantage." This and

the examples already given will show that warning colours are of such a kind and arranged in such a way as to secure conspicuousness, a fact which will be exemplified by still further instances. The primary colours, especially red and yellow, are the commonest in this connection, and the patterns in which they are arranged commonly include spots, bands, and blotches.

Hudson (in *The Naturalist in La Plata*) gives a vivid account of the curious Horned Toad (*Ceratophrys ornata*) (fig. 486) of South America, an aggressive creature in which the poisonous

Fig. 486.—Horned Toad (*Ceratophrys ornata*)

secretion is unusually virulent. Bright-green in colour, with chocolate patches and yellow lips, this Toad is unusually forbidding in appearance, and very conspicuous, except when, half-buried in some damp spot, it lies in wait for the small vertebrates upon which it feeds. "When teased, the creature swells itself out to such an extent one almost expects to see him burst; he follows his tormentors about with slow awkward leaps, his vast mouth wide open, and uttering an incessant harsh, croaking sound."

It is probable that brilliant or striking coloration in some Fishes is to be correlated with poisonous or other unpleasant qualities, but the matter still requires working out. Garstang (quoted by Poulton in *The Colours of Animals*) thinks that an example is afforded by our native Weever-Fish (*Trachinus vipera*), which possesses poison-spines on its gill-covers, and is distinguished by the intense black colour of its first dorsal fin. It is in the habit of burying itself in the sand, this fin alone

projecting, perhaps as a warning to Gurnards and other predaceous Fishes, which prey upon the Dragonet (*Callionymus lyra*), that is not unlike it and has similar habits, though quite devoid of poisonous properties. Annandale (in the paper already quoted) applies this explanation to the Globe-Fishes (genus *Tetrodon*, &c.), "which have earned the name of Balloon-Fish among Europeans, and . . . Pillow-Fish among Malays, by the manner in which they gulp down air into their stomachs, so causing the brilliant coloration of many of them to become conspicuous, and also the spines with which they are armed to be erected."

Numerous instances of warning coloration are to be found among the Protochordates. Some of the compound Ascidians, for example, are very brightly coloured, and this is associated with an unpleasant odour. This correlation of facts suggested to Garstang that they are probably unpalatable to Fishes, and a series of experiments conducted by him proved this actually to be the case. A better example of the scientific method could scarcely be found: hypothesis based on facts, and then confirmed by experiment.

The different species of Acorn-headed Worms (*Balanoglossus*) are more or less brightly coloured and endowed with an unpleasant odour, which makes it probable that they too are possessed of unpalatable qualities.

Warning Colours of Molluscs.—The bright tints of certain Gastropods undoubtedly have a warning significance, though, as in other cases, it is necessary to watch the animals in their natural surroundings before coming to a definite conclusion, for colours and colour-schemes which in themselves are extremely striking may notwithstanding be well adapted to effect concealment when their possessor is "at home". A good example described by Herdman is that of the Sea-Slug (Nudibranch) Eolis, the upper surface of which, as in so many of its kind, is beset with tentacle-like projections (cerata) of brilliant colour, which in this particular case do not harmonize with the natural surroundings. When it is added that the tips of the cerata are provided with stinging cells much like those of Jelly-Fishes and Sea-Anemones, it is not surprising to learn that actual experiment proved Eolis to be unpalatable to fishes.

Striking colours were proved by Garstang to be associated

with inedibility in another Sea-Slug (*Pleurobranchus membranaceus*), which is distinguished by its conspicuous yellow and reddish markings, while its skin secretes an acid. The two examples given will suffice for purposes of illustration, but the bright colours of many other Gastropods, and perhaps also of some bivalve molluscs, may very likely be explained on the same lines.

Warning Colours of Insects.—So many cases have been described of genuine warnings among Insects of various kind, that the difficulty here lies in the selection of material. Good examples are to be found among those members of the Hymenoptera which possess a sting, as, *e.g.*, Wasps and Hornets, which are rendered very conspicuous by alternating rings of black and yellow. Similar markings and colours are exhibited by many Bees, though in their case red is often substituted for yellow.

The largest Butterfly to be found in Britain is the Black-veined Brown (*Anosia erippus*), an American form which appears to be doing well in the struggle for existence, for its area of distribution is steadily getting wider. The wings are of an orange-brown colour, marked with conspicuous black veins, and edged with black upon which white spots are displayed. The under side is as conspicuous as the upper, contrary to the rule for most Butterflies. This form is known to be distasteful to insectivorous animals, and what is even more interesting, Scudder has shown that its eggs and caterpillars are not attacked by certain parasitic insects that play an important part in keeping down the numbers of many other Butterflies and Moths.

The Magpie Moth (*Abraxas grossulariata*) is a good example of a British species possessed of distasteful qualities, and warningly coloured in all three stages of its existence. The caterpillar presents black-and-orange markings on a cream ground, the chrysalis is black with yellow bands, and the wings of the perfect insect are yellowish-white with conspicuous black spots.

Numerous experiments have been conducted by several naturalists regarding the edibility or otherwise of a large number of caterpillars, and as the result of these it may be stated as a general rule that insectivorous animals such as Lizards, Birds, &c., reject conspicuously-coloured forms, but eagerly devour those which are more or less inconspicuous in their natural surroundings. It may therefore fairly be concluded that the colours and markings which make certain caterpillars easy to see are of a warning nature. As

regards adult Butterflies and Moths, colours and markings of the kind may either be genuine warnings or belong to the category of spurious warnings, which will be described in the sequel.

Certain unpalatable Beetles exhibit warning colours, and of these good examples are afforded by the various species of Lady-bird (*Coccinella*), which exhibit red spots on a dark ground.

Warning Colours of Arachnida.—The colours of this group have not been studied in the same detail as those of Insects, and perhaps the best-known case of warning is that afforded by a black-and-red Australian Spider (*Latrodectus scelio*), which has already been described (p. 127).

Warning Colours of Lower Invertebrates.—There can be no doubt that the bright hues of many marine Bristle-Worms have a warning significance, though we have, at present, but little evidence on the subject. There is, however, at least one clear case, *i.e. Polycirrus aurantiacus*, a bright-red worm with very numerous long tentacles of an orange colour, which has been the subject of investigation by Garstang. This animal belongs to a family (*Terebellidæ*) of tube-inhabiting worms, but has given up this mode of life, and is found crawling on stones and sea-weed in pursuit of food. When alarmed it coils itself up so as to be surrounded by its tentacles, and it was shown that these are very distasteful even to voracious sorts of fish. It is an interesting fact that when irritated these tentacles gleam with a phosphorescent light, and this no doubt serves as a warning to the numerous fishes which are in the habit of feeding by night. It would be unsafe, however, to conclude from this and similar cases that the wide-spread phenomenon of phosphorescence always has a warning significance. It no doubt, just like colour, serves various ends (see p. 86), though it cannot be said that its function is well understood in a large number of cases.

Among unsegmented worms it is probable that some of the brightly-coloured conspicuous Planarians, which do not attempt to conceal themselves, possess noxious properties, and Gamble (in *The Cambridge Natural History*) suggests that this may be the case with two large Mediterranean forms, of which one (*Pseudoceros velutinus*) is jet-black, and the other (*Yungia aurantiaca*) bright-orange in hue.

Sea-Anemones and Coral-Animals are often of the most brilliant colours, and these may well be of warning nature, for

the stinging-cells with which these creatures are richly endowed make them very undesirable morsels. The bright hues of many Jelly-Fishes are similarly associated with cells of the sort, and these creatures have been aptly styled "sea-nettles". Although Sponges are not provided with stinging-cells they are often extremely malodorous, and the sharp limy or flinty spicules which abound in their tissues cannot add to their acceptability as an article of diet. Their unpleasant properties are commonly associated with bright colours, orange being a favourite tint.

SPURIOUS WARNING OR MIMICRY

Genuine Warning having now been briefly considered, we may turn to a class of facts coming under the head of Spurious Warning or Mimicry. This embraces cases where an animal devoid of any noxious qualities resembles in form or colour, or both, some other creature which is notoriously unpalatable and advertises this fact by means of warning coloration. It is scarcely necessary to recall a statement made elsewhere to the effect that the so-called mimicry is a purely unconscious process. We are here only concerned with the fact that such mimicking forms would appear to benefit more or less by their resemblance to such well-defended species, being probably treated with respect by natural enemies which would otherwise be pressing in their attentions. It may, however, be as well to state here that there has been too great a tendency to assume offhand that given animals are illustrations of mimicry, warning coloration, or what not, without making them the objects of careful experiment. As a matter of fact the meaning of colours or markings in particular cases is often obscure, and it is better to suspend one's judgment than to come to a hasty conclusion.

Mimicry among Vertebrates. — Wallace (in *Darwinism*) cites the resemblance between Cuckoos and certain other Birds as an instance of imperfect mimicry, and that between East Indian Orioles and Friar Birds as a more perfect example of the same phenomenon. Cuckoos are not well provided with the means of defence, and it is remarkable that the Common Cuckoo is not unlike a Sparrow-hawk in appearance and mode of flight, while other species are known which are liable to be mistaken for Drongo-shrikes, Starlings, and Pheasants respectively. All the forms supposed to be mimicked are more powerful and less liable to be attacked than the Cuckoos which resemble them.

The other case is much more remarkable. Among the Birds inhabiting the Austro-Malay islands (*i.e.* the eastern half of the East Indies) are weak Orioles and comparatively powerful Friar-Birds or Honey-eaters, which are provided with strong beaks and claws. Each of the large islands possesses its own peculiar

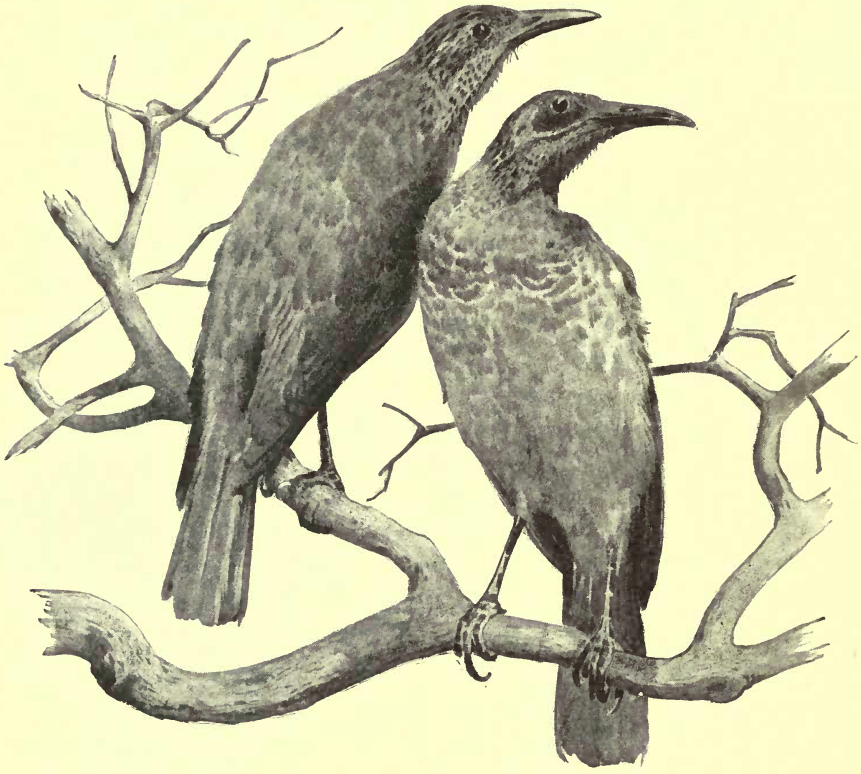


Fig. 487.—A Friar-Bird (*Philemon Timorlaoensis*), right, mimicked by an Oriole (*Oriolus decipiens*), left

species of Friar-Bird, and also a species of Oriole corresponding to it in appearance and thereby enjoying, it is believed, a less worried existence than would otherwise be the case. Forbes discovered such a pair in Timor-laut (*Oriolus decipiens* and *Philemon Timorlaoensis*) (fig. 487), and (in *A Naturalist's Wanderings in the Eastern Archipelago*) speaks of them as follows:—"For some time I was quite puzzled by the difference of behaviour of certain individuals in flocks of these Birds [*i.e.* Honey-eaters] on the trees. Only after the closest comparison of the dead Birds in my hand was the enigma solved by my perceiving that the Birds were distinct species of widely-removed families, and I learned

later that I had obtained new examples of that most curious case of mimicry first detected (among Birds) by Mr. Wallace, where an Oriole constantly derives protection from its foes by acquiring the dress of a Bird always of the same powerful and gregarious Honey-eaters. . . . When my collection was laid out for description by Dr. Sclater, the Oriole's and the Honey-eater's dress were so strikingly similar that the sharp eye of that distinguished ornithologist was deceived, and the two birds were described by him as the same species."

Among Reptiles, Poisonous Snakes are so universally feared by other animals that we should naturally expect them to be mimicked by harmless forms. As in the case of Birds, the imitation may be either of a general kind or carried out into detail. The former is exemplified by a number of non-poisonous Snakes which, when threatened or attacked, behave as if they were venomous. The same thing is true for the harmless Blind-worm, which is not a snake at all, but a snake-like Lizard.

Probably the best example of Poisonous Serpents exhibiting warning colours copied by innocuous species is afforded by the Coral Snakes of South America and the West Indies (see p. 303). Different species of these are copied with extreme accuracy by harmless Snakes belonging to several genera, and a particular poisonous species may have more than one kind of imitator.

Mimicry among Insects.—The phenomena of mimicry are better illustrated by Insects than any other animals, and indeed the matter was first placed on a scientific basis by the researches of Bates upon the Butterflies of the Amazon valley. It will therefore be convenient to make Butterflies and Moths our point of departure. There are three sub-families of the former which have their head-quarters in the tropics, and are possessed of properties which cause them to be avoided by insectivorous animals. The technical names of these three groups are Danaids, Acræids, and Heliconids, the members of all three being distinguished by colours and patterns that are regarded as having a warning meaning.

Heliconids.—This sub-family is limited to and very characteristic of tropical America, and it is the one specially studied by Bates as mentioned above. He showed that a considerable number of the included species are copied in a very faithful

manner by palatable Butterflies belonging to several other families, and also by certain Moths. Many of the mimicking species belong to the Pieridæ, which includes the common white Butterflies of our fields and gardens, and these are naturally so unlike the forms they mimic that Wallace remarks (in *Darwinism*):—"These differences are as large and important as those between pigs and sheep, or between swallows and sparrows; while English entomologists will best understand the case by supposing that a species of Pieris in this country was coloured and shaped like a small tortoise-shell, while another species on the Continent was equally like a Camberwell beauty—so like in both cases as to be mistaken when on the wing, and the difference only to be detected by close examination".

The *Danaids* are found in the warmer parts both of the Old and New Worlds, though they are most abundant in the tropical parts of Asia. Their various species are mimicked to a very large extent, and one of these, the Black-veined Brown or Monarch (*Anosia erippus*), is interesting as an American form which has extended its range to this country. In its original home it is imitated by a harmless Butterfly (*Limenitis misippus*) belonging to another family and closely allied to one of our native forms, the White Admiral (*Limenitis sibylla*).

It is evidently more important for the well-being of the race that the female should be protected than the male, and it is a fact that only the female Butterfly in some mimicking species assumes the garb of an unpalatable species living in the same area. The difference between the two sexes in such cases is so great that they are liable to be mistaken for distinct species. But this is quite a simple matter by comparison with a case described in detail by Trimen, in which the females of a South African Swallow-tail Butterfly (*Papilio merope*) are of three different sorts, unlike the male and unlike one another. The reason for this is, that each of the three kinds mimics a distinct species of Danais (*D. echeria*, *D. niavius*, and *D. chrysippus*). Comparison with a closely-allied Swallow-tail (*Papilio meriones*) from Madagascar gives us an idea of what the female of *P. merope* was originally like. In this case there is no question of mimicry, and the two sexes are very similar.

Acræids.—The members of the third Butterfly group notorious for inedibility, *i.e.* the Acræids, is found chiefly in tropical Africa,

UNIV. OF CALIFORNIA

ANIMAL COLORATION

UNIV. OF
CALIFORNIA

where the various species are mimicked by a number of edible Butterflies belonging to other families.

Mimicking Moths.—The three groups of Lepidoptera so far mentioned are by no means the only ones which are more or less endowed with noxious properties, as a result of which they have been the subject of imitation by their cousins. Cases among Moths are known even among British forms, the most familiar example being that of the White Ermine Moth (*Spilosoma menthastri*), which is copied by the female of the Muslin Moth (*Diaphora mendica*). The colour is white, spotted with black, and the species imitated is known to be unpopular among insect-eating animals.

Clear-wing Moths.—Some of the adult Lepidoptera imitate members of other orders better endowed than they are with means of defence. A very good instance of this is afforded by the "clear-wing" Moths, so-called because the wing-membranes have to a large extent lost the covering of scales which is so characteristic of the lepidopterous order. Our two native species of Hornet Clear-wing (*Trochilium apiformis* and *T. crabroniformis*), for example, look very like Hornets as a result of this special character, with accompanying modifications of the proportions, colours, and markings of the body. It is even stated that when caught they make a pretence of stinging. That this is really a case of mimicry is, however, doubted by some naturalists, as, *e.g.*, by Sharp, who, speaking of the Clear-wing family (in *The Cambridge Natural History*), says:—"Some of the species have a certain resemblance to Hymenoptera, which is probably in most, if not in all, cases merely incidental".

Mimicking Caterpillars.—The larvæ or caterpillars of a number of Butterflies and Moths would appear also to be protected by mimetic devices, including more particularly the assumption, when frightened, of alarming or warning attitudes of deceptive nature. A remarkable case is that of the caterpillar of the Lobster Moth (*Stauropus fagi*) (fig. 488), which, under ordinary circumstances, is more or less protected by its resemblance in colour and form to a distorted and withered leaf. When alarmed, however, it rears up the ends of its body and vibrates, presenting a sort of bogey-like aspect, which may be described as half spider-like with the other half bug-like. Another remarkable caterpillar is that of the Puss-Moth (*Cerura vinula*), which, when frightened,

assumes a comic appearance which has been compared to that of a small reptile, the front end being broadened out into a surface looking like the caricature of a face with red margin and dark eyes, while from the hinder end two pink whips are shot out, these being specializations of the last pair of larval legs (pro-legs). A gland from which an irritant acid fluid can be squirted out opens on the lower part of the apparent "face". Some large

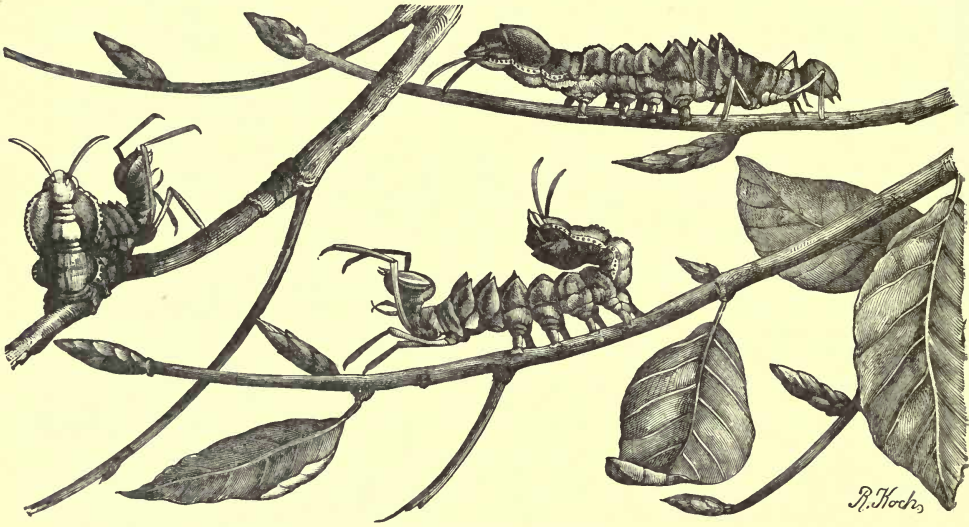


Fig. 488.—Caterpillars of the Lobster Moth (*Stauropus fagi*)

caterpillars possess eye-like markings which give them a remote resemblance to snakes, as, for example, in the case of those belonging to the Large and Small Elephant Hawk-Moths (*Chærocampa elpenor* and *C. porcellus*).

Mimicking Flies.—A good example of mimicry among two-winged flies (Diptera) is that of the Drone-Fly (*Eristalis tenax*) (see fig. 390), which closely resembles a bee in appearance and movements, besides which its loud buzz is suggestive of the more powerful insect it is generally supposed to imitate.

Mimicking Beetles.—Beetles (Coleoptera) present a variety of cases usually believed to illustrate mimicry. As in the case of insects belonging to other orders, a number of beetles would appear to ward off attack by taking on the appearance of wasps or bees. Poulton instances a British form (*Clytus arietis*) which looks and moves very like a wasp, although the wings of the latter are not imitated. This, however, is not so remarkable as

a Bornean beetle (*Coloborhombus fasciatipennis*), which is extremely like a large black wasp (*Mygnimia aviculus*) from the same region. Beetles usually keep their transparent hind-wings folded up except during flight, and covered over by the hard fore-wings, which constitute wing-cases (elytra). But here the latter are reduced to inconspicuous scales, while the former are kept expanded, in which condition they closely resemble in form and colouring the wings of the wasp.

Tiger-Beetles are avoided on account of their ferocity, many Weevils because they are hard and indigestible, while other species of Coleoptera are protected by *stink-glands*. All these protected groups are mimicked by their weaker brethren.

Mimicking Grasshoppers and Crickets.—The cockroach and grasshopper order (Orthoptera) is rich in illustrations of mimicry. Semper (in *Animal Life*), for example, cites two Philippine Grasshoppers, one of which (*Scepastus pachyrhyncoides*) presents a deceptive resemblance to a hard weevil (*Apocyrtus*), while the other is a respectable imitation (*Phoraspis*) of an unpalatable lady-bird beetle (*Coccinella*). A Cricket (*Condylodeira tricondyloides*) from the same islands is wonderfully like a tiger-beetle (species of *Tricondyla*) found in the same part of the world.

Mimicking Orthoptera.—Some of the Orthoptera when alarmed display eye-like markings, reminding one of the caterpillars already described. In the Praying Mantis (*Mantis religiosa*) and other members of the same family such markings are found on the inner sides of the thighs (femora) of the fore-legs, which members are usually forwardly-directed, ready to catch insect prey. An interesting new theory regarding such markings is quoted by Annandale (in the paper already mentioned), who says:—"I do not know that a function has ever been assigned to marks situated in this position except by the Russian naturalist Porschinsky. . . . [He] has a theory that all eye-like markings on insects represent glands, which may be imagined to secrete a noxious fluid. He supposes that such markings simulate the liquid which has issued forth, with the blue sky or some other object reflected in it, and points out that the display of such spots is sometimes accompanied by a sound which might be taken to imitate liquid hissing out of a narrow opening, such as the duct of a gland. *Mantis religiosa* is one of his examples. He says that there is a large blue 'eye',

ringed with black, on the inner surface of the femur of the fore-limb in this species; and that the eye is concealed when the mantis is at rest, because the two limbs are held folded together in front of the body. 'But when danger threatens', to quote his own words, 'the praying mantis assumes a very peculiar and interesting attitude, which, so far as I know, was first described by Goureau. The long and narrow pro-thorax assumes a vertical position, so that the body is supported only by its two pairs of hind-legs. Under these circumstances the insect widely separates the front pair of legs, giving to its long femora a horizontal position, so that the distal ends of them are directed on opposite sides. In this way the eye-spots, which are situated at their bases, stand out conspicuously and are most obvious owing to their colour. The tibiæ of the front pair of legs are directed vertically upwards. At the same time the insect lifts up its tegmina [*i.e.* wing-covers] and unrolls its wings, giving them a horizontal position, and it begins quickly to raise and lower its abdomen, which, rubbing against the posterior edge of the wings at the same time as these continual movements, produces a sound. The mantis can produce the latter artificially by rubbing its wings against some extraneous object.'" All this is very speculative, but it would appear to be, at any rate, an instance of a spurious warning.

Mimicking Plant-Bugs.—The last case of mimicry among insects to be described here is in some ways the most remarkable of all. An account has elsewhere been given (see p. 208) of the leaf-cutting ants of South America, which cut off and carry home pieces of leaf. W. L. Sclater has pointed out that, associated with these ants, there is a kind of plant-bug which, in colour and shape, actually resembles such an ant, together with the piece of leaf it is carrying (fig. 422).

Mimicry among Spiders.—Spiders often form a favourite diet with insectivorous birds, but it would appear that in various parts of the world some kinds of these creatures obtain a little peace and quietness by pretending to be ants. A very instructive North American species (*Synageles picata*) of the kind is described by Peckam. Not only does this form resemble an ant in general form, but also in gait and general behaviour; while its second pair of legs are held up like feelers, the remaining three pairs masquerading as the six legs of an insect.

A sufficient number of examples illustrating special bodily characteristics have now been given, though it must not be supposed to be a phenomenon limited to the groups which have been drawn upon. We pass on to protective measures constituted by certain habits not necessarily associated with peculiarities of colour.

CHAPTER XXVII

ANIMAL DEFENCES—SPECIAL PRECAUTIONARY HABITS

We have so far considered PRECAUTIONARY MEASURES whereby enemies are warded off, so far as they depend upon bodily characteristics producing inconspicuousness or studied conspicuousness, but certain PRECAUTIONARY HABITS of quite different kind are equally important, and deserve a little attention. A great deal of what might be said has of necessity been anticipated, for the form and structure of animals can only be properly understood when considered along with habits and surroundings.

It has already been pointed out that animals are most exposed to the attacks of enemies when they are on the move. Excluding forms such as sponges, corals, sea-lilies, &c., we may say that movements are more or less necessary for the purpose of obtaining food. The risk thus incurred, however, may be reduced by feeding at suitable times and in suitable places, while safety between whiles may be gained by the existence of dwellings, retreats, and temporary resting-places.

FEEDING AT FAVOURABLE TIMES—NOCTURNAL ANIMALS. (Fig. 489)

This subject requires working out, so that only a few points can be here presented for consideration. A very large number of those animals most exposed to attack turn night into day, and, in certain cases at any rate, the nocturnal habit may have been acquired as a protective measure. It is necessary here, however, to be guarded in statement, since many factors have to be considered, and consequently every case must be weighed carefully. It is not unlikely, for example, that the nocturnal habit may be a very ancient one, having no special protective significance, and that its continuance in many recent forms is due to

Fig. 489.—Heads of Nocturnal Animals

1, Hawk-Owl (*Surnia ulula*); 2, Owl-Parrot (*Stringops habroptilus*); 3, Slow Lemur (*Nycticebus tardigradus*); 4, Spectre-Tarsier (*Tarsius spectrum*); 5, Night-Monkey (*Nyctipithecus trivirgatus*); 6, Egyptian Jerboa (*Dipus jaculus*); 7, Wall-Gecko (*Tarentola Mauritanica*); 8, Flying Frog (*Rhacophorus Reintwardti*); 9, Phosphorescent Sardine (*Scopelus engraulis*).

the action of heredity through a long series of ages. In very hot climates, too, the question of temperature has to be taken into consideration. And even where we may suppose the habit to be protective it can only be partially effectual, for many predaceous animals are notoriously nocturnal, and some of them, at any rate, have become so because their prey took to feeding at night as a protective measure. We may feel sure that every new life-preserving device that has been evolved among animals which are preyed upon results in some counter-move among the aggressors.

Some few monkeys are nocturnal in habit, and among these may be particularly mentioned the Owl-faced Night-Monkeys (species of *Nyctipithecus*), widely distributed in South America. The time at which these small animals feed is indicated, as in many other cases, by their large eyes, around which the hair is arranged in a radiating manner, the two features combined giving a very owl-like appearance. The chief enemies of the inhabitants of South American forests are climbing snakes and carnivores, and probably the attacks of these are to some extent avoided by the practice of feeding at night. But it must be borne in mind that these night-monkeys themselves feed upon insects and birds, which are more easy to surprise in the dark, so that in this case the nocturnal habit would appear to serve a double purpose.

Primitive groups of animals often include a number of nocturnal members, and this is well seen in the order of Lemurs, many of the smaller kinds of which are endowed with large staring eyes. Examples are the Aye-aye (*Chiromys*) of Madagascar, and the Pottos (*Perodicticus* and *Arctocebus*) and Galagos (*Otolicnus*) of Continental Africa, together with the Loris (*Nycticebus*) and Spectre-Tarsiers (*Tarsius*) of the East Indies. As, however, most of these live largely or mainly upon insects and small vertebrates, the night-feeding habit is probably useful in two ways, as in the case of the owl-faced night-monkeys already described. If, as has been asserted, the West African Galagos subsist only upon fruit and gum, the nocturnal arrangement may possibly be purely protective.

Bats are perhaps the most thorough-going night-forms among Mammals, but as the great majority prey at dusk upon insects which fly at that time, the habit is probably in relation to this.

Even the Fruit-Bats (*Pteropus*) partly affect an animal diet, devouring various small vertebrates, from fishes to mammals. The large majority of the Insectivora are night-feeders, probably because their prey is more easily secured at that time than for the sake of protection.

So powerful a creature as the Elephant seems at first sight to require no special means of protection, and its nocturnal habits are no doubt largely due to its dislike of heat and desire to avoid the unpleasant attention of flies. No animal, however, is more persecuted by the arch-enemy man, who is more particularly given to hunting during the day, so that nocturnal forms have the best chance of avoiding him.

Many of the Ungulates feed at night, partly, it would seem, for the sake of thereby lessening the chance of attack, but also in order to avoid heat and flies. The habit is particularly well developed in the case of certain forms which affect damp surroundings and wooded country, of which good examples are afforded by Hippopotami, Tapirs, Swine, some kinds of Deer, and Cape Buffaloes. Regarding the Hippopotamus, Vogt (in *The Natural History of Animals*) says:—"The hippopotamus is on the whole a nocturnal animal, and where it has made acquaintance with firearms leaves the water only by night, or if by day, only to bask in the sun on sand-banks and islands out of the range of bullets". Regarding the Cape Buffalo the same writer remarks:—"It is fond of plains and marshy forests, and delights to remain the whole day buried in mud up to the shoulders in order to protect itself against insects by which it is infested, and from which it is partly delivered by birds that settle on its back".

The Gnawers or Rodents constitute a very large and widely-distributed order of Mammals, living mainly on vegetable food, mostly of small size and ill-provided with the means of defence, on which account they are particularly liable to the attacks of predaceous forms. Taking all these facts into consideration, we shall probably not be far wrong in attributing a protective function to the nocturnal habits by which most of them are characterized. Rats and Mice may be regarded as a case in point, and the ordinary House-mouse (*Mus musculus*) in particular would have but a poor chance of existence if all its depredations were carried on during the day. Another feature of interest in this case is that it presents a pretty clear case of a protective habit which

has been rendered less useful because it has also been adopted by certain natural enemies, *i.e.* Owls, which are among the most persistent foes of small rodents. In these birds the nocturnal habit has almost certainly been acquired for aggressive purposes. It is interesting to note that some members of the order possess the large eyes characteristic of thorough-going nocturnal species. This is the case, *e.g.*, with the Egyptian Jerboa (*Dipus Ægyptiacus*).

The Edentates, like many other ancient and primitive groups, are markedly nocturnal, and the leaf-eating Sloths in particular probably derive a good deal of protection from the habit. The same remarks apply to the more defenceless vegetable-feeders among the Marsupials, such as the Phalangers, Koalas, and Wombats. The more powerful Kangaroos, on the other hand, feed by day, while the rapacious Dasyures and the Tasmanian Wolf prey at night on weaker animals.

The feeble members of the lowest group of Mammals, the Monotremes, are nocturnal in habit, the Spiny Ant-eaters entirely, and the Duck-billed Platypus largely so.

Birds are essentially a day-loving class, and when nocturnal habits have been acquired, as in owls and night-jars, they chiefly have reference to the nature of the prey. In some few cases, however, the night-feeding practice would appear to have a protective meaning, as, *e.g.*, in two New Zealand birds, the Owl-Parrot or Kakapo (*Stringops habroptilus*) and the Kiwi (*Apteryx*). The former feeds chiefly on vegetable matter, and being practically devoid of flying powers is singularly defenceless; its time of activity might be divined by the owl-like character of its head. The Kiwi is the smallest and most defenceless of the running birds.

Among Reptiles,—Crocodiles and large Snakes, such as Pythons, are respectively largely and entirely nocturnal, but protection is not the end to be attained. A case, however, of which the meaning is probably partly protective, is afforded by most of the species of the little climbing lizards known as Geckos, of which large eyes are characteristic, and these organs exhibit the vertical pupils often found among nocturnal forms. The specialization even here, however, has no doubt as much reference to the pursuit of certain sorts of insects under favourable conditions as to protection; indeed, the former may be the chief object of the habit.

Although Amphibians constitute a group which is predomi-

natingly nocturnal, this habit, though perhaps partly protective, is primarily due to the fact that a large amount of moisture is essential to these creatures, for any great amount of evaporation from their skin (which helps in breathing) would be deleterious, if not fatal. Large eyes are often possessed by them, and the Flying Frog (species of *Rhacophorus*) are particularly well endowed in this respect.

Many Fishes are of nocturnal habit, and there can be little doubt that in some cases protection is one of the ends thus attained. But, precisely as in land-vertebrates, the value of this arrangement is much reduced by the fact that predaceous forms may have the same habit. As fishes commonly discover their food by means of touch and smell, darkness is not the same hindrance to feeding that might be anticipated.

Many Invertebrates are nocturnal, but our knowledge of their habits is too scanty in most cases to permit of more than somewhat vague conjecture. It is highly probable, however, that the practice of feeding at night exemplified by such insects as Cockroaches, Crickets, and Moths acts more or less as a protection. Nor is it impossible that this may be one of the ends served by the phosphorescence of certain insects. This phenomenon is perhaps most strikingly seen among the Fire-Flies, which constitute a family (*Lampyridæ*) of tropical beetles.

Many marine invertebrates, belonging to widely-differing groups, are more active by night than day. Hosts of creatures which during the latter are submerged to some depth rise to the surface when the sun goes down, especially when the weather is calm. It is not known how far this habit has to do with protection, nor is the use of the phosphorescence characteristic of many such forms fully understood.

We have now seen that certain animals gain a measure of protection from their foes by feeding during the night, but as the same end is attained in other cases by feeding during the day, it may be in such a way as to court rather than avoid observation. Space forbids the mention of more than a few typical instances.

FEEDING AT FAVOURABLE TIMES—DIURNAL ANIMALS

Many herbivorous animals possessed of rapid means of progression, and endowed with keen senses by which the approach

of enemies may be perceived, feed boldly during the day, relying upon their powers of rapid retreat in the case of attack. This is particularly noticeable in those species which obtain their food in places where a wide outlook over the surrounding country is obtainable. Wild Horses and their allies, Giraffes, Antelopes, Goats, Sheep, Kangaroos, and Ostriches, will serve as examples.

It is also obvious that species exhibiting *warning coloration*, and mimicking animals, are specially equipped to secure their protection during the day, provided that the current interpretation of these phenomena rests on a firm basis. The same thing is probably very largely true of *protective resemblance*, whether this is special or general, as after dusk no useful end can be served by such arrangements, except perhaps on bright moonlight nights.

Having now discussed in a tentative fashion cases where some amount of protection is gained by animals which are active at certain Times, we come to instances where the Place of feeding is useful in this respect.

ANIMALS PROTECTED BY FEEDING IN SUITABLE PLACES

Under this heading may be, in the first place, included all those forms which exhibit *protective resemblance*, whether general or special. It is quite clear, for example, that a colour-scheme which harmonizes with certain surroundings so as to result in inconspicuousness, may be very conspicuous if viewed against some other kind of background. Romanes (in *Darwin and After Darwin*), in describing a particularly good instance of this, says:—" . . . Hares and rabbits . . . instinctively crouch upon those surfaces the colours of which they resemble; and I have often remarked that if, on account of any individual peculiarity of coloration, the animal is not able thus to secure concealment, it nevertheless exhibits the instinct of crouching which is of benefit to all its kind, although, from the accident of its own abnormal colouring, this instinct is then actually detrimental to the animal itself. For example, every sportsman must have noticed that the somewhat rare melanic [*i.e.* black] variety of the common rabbit will crouch as steadily as the normal brownish-grey type, notwithstanding that, owing to its abnormal colour, a 'nigger-rabbit' thus renders itself the most conspicuous object in the landscape."

As mentioned in a preceding paragraph, certain forms endowed with the power of rapid movement are comparatively safe when feeding in places from which a wide outlook is obtainable, and this may be flat or undulating country, such as is favoured by giraffes, many antelopes, wild horses, kangaroos, and ostriches, or it may be of the mountainous rocky character affected by wild sheep and goats, conies, baboons, and many other creatures. Even where the powers of locomotion are not very extraordinary, open places afford comparatively safe feeding-ground if a suitable retreat is close by. Young Rabbits, for example, commonly feed quite close to the mouth of their burrow, into which they immediately disappear on the least alarm. Similarly arboreal forms which feed to some extent on the ground, as is the case with a number of Old-World monkeys, are pretty safe so long as trees are at hand. This naturally suggests the next case to be considered, *i.e.* the arboreal or tree-inhabiting habit as a means of protection.

Arboreal Animals.—Several causes have had to do with the evolution of climbing animals, and the remarks already made in reference to the nocturnal habit (see p. 318) are equally applicable here. Such an infinite variety of animals exist, and they increase so rapidly, that the struggle for existence is exceedingly keen, and every possible kind of food is liable to be commandeered. And since (see p. 164) practically all animals are dependent on plants either directly or indirectly, it would be extraordinary if woods and forests had not attracted a large population, which has become more or less specialized in accordance with the exigencies of an arboreal life. The following remarks made by Bates (in *The Naturalist on the Amazons*), in reference to the animal population of the virgin forests of South America, forcibly illustrate this point. After speaking of certain climbing plants, he says:—"The number and variety of climbing trees in the Amazon forests are interesting, taken in connection with the fact of the very general tendency of the animals also to become climbers. All the Amazonian—and in fact all South American—monkeys are climbers. There is no group answering to the baboons of the Old World, which live on the ground. The Gallinaceous birds of the country, the representatives of the fowls and pheasants of Asia and Africa, are all adapted by the position of the toes to perch on trees, and it is only on trees, at a great height, that they

are to be seen. A genus of Plantigrade Carnivora, allied to the bears (*Cercoleptes*), found only in the Amazonian forests, is entirely arboreal, and has a long flexible tail like that of certain monkeys. Many other similar instances could be enumerated, but I will mention only the Geodephaga, or carnivorous ground beetles, a great proportion of whose genera and species in these forest regions are, by the structure of their feet, fitted to live exclusively on the branches and leaves of trees. . . . The largest and most interesting portion of the Brazilian mammal fauna is arboreal in its habits; this feature of the animal denizens of these forests I have already alluded to. The most *intensely* arboreal animals in the world are the South American monkeys of the family Cebidæ, many of which have a fifth hand for climbing in their prehensile tails, adapted for this function by their strong muscular development, and the naked palms under their tips. This seems to teach us that the South American fauna has been slowly adapted to a forest life, and therefore that extensive forests must have always existed since the region was first peopled by mammalia." Enough has been said to show that food-supply alone must have had a great deal to do with the evolution of arboreal forms, and it would be easy to draw up a number of cases on the model of *The House that Jack Built* to illustrate chains of causes and effects that have arisen as a result. Trees have produced fruits and seeds, fruits and seeds have led to the evolution of fruit- and seed-eating monkeys, &c., fruit- and seed-eating monkeys, &c., have led to the specialization of climbing carnivores. Similarly the wood and bark of trees have afforded nutriment to various insects, and this has resulted in the evolution of woodpeckers and other arboreal insectivorous forms.

All this may be the truth, and nothing but the truth, but it is by no means the whole truth. It is practically certain that some animals have taken to feed among trees, not merely for the sake of the aliment there present, but also in order to avoid enemies living upon the ground. In such cases the arboreal habit is partly a *protective measure*. Why, for example, should the carnivorous ground-beetles of the Amazon forests have taken to live among the trees, as stated by Bates in the extract given above? A possible solution to this is given by the same zoologist elsewhere. "It is vain to look for the Geodephaga, or carnivorous beetles, under stones, or anywhere, indeed, in open, sunny places. The

terrestrial forms of this interesting family, which abound in England and temperate countries generally, are scarce in the neighbourhood of Para; in fact I only met with four or five species. On the other hand, the purely arboreal kinds were rather numerous. The contrary of this happens in northern latitudes, where the great majority of the species and genera are exclusively terrestrial. . . . The remarkable scarcity of ground-beetles is doubtless attributable to the number of ants and termites which people every inch of surface in all shady places, and which would most likely destroy the larvæ of Coleoptera."

Some of the members of certain ancient groups now on the decline have taken to an arboreal life, trees affording them a refuge which at the same time yields an abundance of food. Such, for example, are the defenceless leaf-eating Sloths, creatures of comparatively small size, which are remarkably specialized in structure to fit them for their life among the trees of the South American forests. The explanation here suggested is supported by the fact that tree-dwelling sloths are a young group, geologically speaking, and find their nearest allies among extinct forms in the Ground-Sloths, which, though they appear to have lived on foliage, were quite unable to climb. Some of these creatures attained a very large size, Megatherium, for example, rivalling the elephant in that respect. The Neomylodon of Patagonia, perhaps even yet living, is, or was, a similar kind of animal.

Parachute Animals.—Certain climbing forms have developed folds of skin converting them into what may be termed "parachute animals", an arrangement which facilitates progress from one tree to another, and is protective in so far as it may be supposed to facilitate escape from enemies. Such among mammals are Flying Squirrels, while lizards present the case of Flying Dragons, and Flying Frogs are found among amphibians. From this kind of apology for flight we naturally pass to flying animals proper.

Flying Animals.—The geological record proves that Insects led the way in the conquest of the air, thereby vastly facilitating their progress from place to place in pursuit of prey, and affording more or less protection by thwarting many of the attacks of wingless enemies. And it is noteworthy that the oldest known insects find their nearest allies among recent Orthoptera of the cockroach

kind, and were presumably vegetarian. The evolution of flying insects made the realm of air a new food-producing territory, and this may have been one of the factors helping to bring about the evolution of Birds, Flying Reptiles (long since extinct), and Bats. Be that as it may, the flying habit in recent birds and bats affords a certain amount of protection, though the device is so ancient that its efficacy in this respect has been largely discounted by the appearance of rapacious types with powers of flight. Insects, the oldest fliers, have naturally suffered most from this cause, for they prey upon one another, and are mercilessly thinned out by birds and bats. Birds, which come next in order of antiquity, prey upon one another, and it would appear that bats, the youngest (so far as our knowledge goes) of flying groups, enjoy the largest share of protection from their power of progression through the air. It would be rash to even conjecture why flying reptiles should have become extinct. Perhaps the competition with birds became too keen; at any rate the experiment turned out a failure, though in justice to their class it should be remembered that birds are probably of reptilian stock, which may therefore be said to have made two series of attempts at flight, conducted on different lines, and one of which has been crowned with success.

Underground Animals.—We have now seen how certain forms of life have withdrawn themselves from the keen competition which takes place upon the surface of the ground, and gained more or less protection, while at the same time improving their chances of getting sufficient food, by adopting an *arboreal* or an *aerial* habit. Another line has been struck out by creatures which have taken to live entirely underground. The subterranean parts of plants and the organic matter contained in earth have offered food to vegetarian forms, and these again have led to the evolution of carnivorous species suited for progression below the surface of the soil. This way of life has proved of advantage to many sorts of animal, since it affords protection as well as food.

Among vegetarian forms of the kind may be more particularly mentioned Earth-Worms, certain adult Insects (*e.g.* Mole-Crickets), and many Insect larvæ (*e.g.* Cockchafer Grubs). Among carnivorous forms most specialized in accordance with underground habits are found members of widely-different groups. As to Mammals, we have, for instance, the Moles, belonging to the large and primitive order of Insectivora, and the Pouched-Mole

(*Notoryctes*) of Australian deserts, belonging to the still lower order of Marsupialia. Such Reptiles as the small degenerate Burrowing-Snakes (*Typhlopidæ*) and certain Snake-like Lizards (*Amphisbænidæ*) are further examples, and still another instance is afforded by the curious tropical Cæcilians, constituting an order in Amphibia which present a superficial resemblance to Serpents. It may be noted here, too, that a rich fauna inhabits certain caves.

This section may appropriately be concluded by a few remarks on protective measures as to place of feeding which have been adopted by aquatic forms.

Certain Marine Animals which have gained Protection by Migrating to New Feeding-grounds.—There is good reason for believing that the sea is the original home of life, and from very ancient times its shallow waters up to high-tide mark have been the scene of very keen competition for food. By migration from shallow water in different directions certain forms tapped fresh sources of food-supply, and, for a time at any rate, succeeded in reducing the toll levied upon them by predaceous forms. It is extremely probable that many Land-Animals originally took origin from the fauna existing between tide-marks, the conditions there being such as to afford a preparatory training for terrestrial existence pure and simple. Backboned Land-Animals most likely sprang from freshwater forms (see next paragraph), and these again claim marine ancestry. The land, once peopled, soon presented a struggle for existence as keen as that obtaining in the sea, and in the ways already indicated the pressure was partially relieved. Another particularly interesting case here deserves mention, *i.e.* that of various forms which, after becoming thoroughgoing land animals, returned to the original home of life, and underwent a second series of specializations fitting them for a new sort of marine existence. In this way two of the orders of Mammals have been evolved: Cetacea, including Whales, Porpoises, &c.; and Sirenia, comprising Manatees and Dugongs. Among the Carnivora, too, we have the Pinnipedia (Walruses, Sea-Lions, and Seals), which live more in the sea than out of it. A similar policy has been pursued by members of some other classes of land Vertebrates. Penguins, for example, have given up flight, and spend a large part of their lives in the sea, using their modified wings as paddles. Several groups of extinct Reptiles appear to have lived entirely in the sea; why they died

out it is difficult to understand. One reptilian experiment in this direction, however, has been more successful, for Marine Snakes thrive in the Indian Ocean. Among Invertebrates the lung-breathing Snails and Slugs (Pulmonata) are very much specialized to fit them for a life on land, yet certain slugs (species of *Oncidium*, &c.) have taken to a shore-life, though they can scarcely be called marine. Insects are perhaps the most characteristic of land-animals, yet a few of them are found living on the surface of the sea. Certain allies of the Earth-Worm have been found burrowing along the shore.

Rivers and Lakes as a Haven of Refuge.—The waters of the land have afforded protection to a number of hard-pressed marine forms, estuarine conditions affording a sort of half-way house. Fishes afford the most striking illustration, for all of those inhabiting rivers and lakes have probably sprung from a marine stock. At the present time, for example, Lung-Fishes (Dipnoi) are limited to some of the rivers of Africa, South America, and Australia, though originally the group to which they belong included only marine species, as shown by geological evidence. All the marine species have now become extinct, having been unable to cope with the competition offered by other forms, but those which have taken to fresh water have so far been able to hold their own. Amphibians appear to have been evolved from ancestors resembling Lung-Fishes in many ways, while Reptiles, Birds, and Mammals probably sprang from an amphibian stock.

Floating Aquatic Forms (Plankton).—The surface layers of the sea swarm with animal life, and have very likely (though this is not quite certain) received their population from shallower water. The gulf-weed which floats on the Sargasso Sea in the North Atlantic has quite a fauna of its own, and no doubt plants took to floating life before animals, which were attracted by the food-supply thus offered. There is reason to believe that in very remote geological times far larger areas of the ocean surface were covered by drifting sea-weed than is the case at present. Such floating animals are also found in lakes.

Deep-water Life (Benthos).—Profound ocean depths are peopled by a large and strange collection of animal forms, many of which seem to have been driven out of shallower water by the force of competition. Otherwise they would most likely have

become extinct, so that their taking to deep-sea life has proved a protective measure. The nature of these forms and the conditions under which they live will be discussed elsewhere. Lakes also possess a deep-water fauna.

Burrowing Marine Forms.—As explained elsewhere (p. 249), many marine Bivalve Molluscs provided with siphons are able to feed and breathe when buried in sand or mud, the tips of the siphons only projecting. This is a very effective protective measure, especially as sense-organs are present, which enable their owner to distinguish between degrees of light and darkness. As one result of this, a passing shadow, often an indication of the presence of enemies, causes the siphons to be drawn in. Other bivalves burrow in stone or wood, and the same is true for the members of some other groups. A large number of Marine Worms dwell in mud or sand like their terrestrial brethren, and enjoy a certain amount of protection as a result, though here again certain predaceous forms have adopted the same mode of life with intentions the reverse of benevolent.

CHAPTER XXVIII

ANIMAL DEFENCES—PASSIVE DEFENCE

A sketch having now been given of PRECAUTIONARY MEASURES, we come to the various kinds of RESISTANCE, by which the attacks of enemies when delivered are met, and, it may be, foiled.

It is clear that defence may be either PASSIVE or ACTIVE, and the two cases are best considered separately.

PASSIVE DEFENCE

As in the case of Precautionary Measures, it may conduce to clearness if we look at this matter from two different but closely-connected standpoints: *i.e.* (1) Bodily Characteristics; (2) Special Habits; (3) Fecundity, as a means of defending the species, also requires consideration.

BODILY CHARACTERISTICS OF USE IN PASSIVE DEFENCE

UNPALATABLENESS AND INDIGESTIBILITY. — In dealing with warning coloration (see pp. 301–309), it has been pointed out that unpalatable or indigestible forms are often distinguished by colours and markings which are more striking than artistic. Such animals, however, are liable to "experimental tasting" on the part of inexperienced enemies, and though some of these, if rapidly ejected on account of their objectionable properties, may escape with their lives, many or most are not so fortunate. Even these, however, contribute to the defence of the *species*, as they assist in the education of enemies. At least this is the current explanation, and, so far as some animals are concerned, it is based on actual experiments, though whether these are sufficiently numerous and extended to form a safe basis for generalization has been doubted. However this may be, we are on safe ground as regards those animals which are provided

with defensive plates and spines which oppose considerable resistance to attack.

Armoured Animals.—Both plate-armour and spiny coverings are found in many groups of the animal kingdom, the former simply warding off teeth and claws, while the latter are calculated to inflict injury upon enemies coming to close quarters. Several orders of Mammals possess arrangements of the kind. Among Edentates, for instance, Armadilloes are protected by cuirasses composed of bony plates, and Pangolins by scale-armour. Among Rodents, the Porcupines are clothed with effective spines (sometimes barbed), as are Hedgehogs among Insectivores, and Spiny Ant-Eaters among Monotremes.

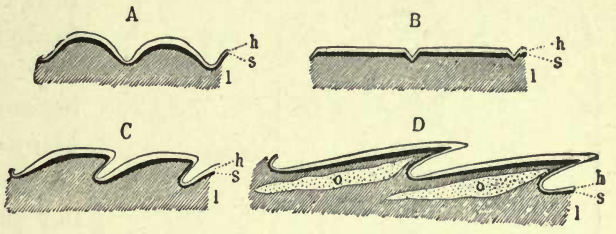


Fig. 490.—Diagram of varieties of Reptilian Armour, as seen in section A, Granular scales. B, Flat scales or shields. C, Overlapping scales. D, The same, with underlying bony plates (scutes). *h*, Hard outer layer of epidermis; *s*, deeper layer of epidermis; *l*, dermis; *o*, bony plates.

Birds are provided with scale-armour on their legs, and their feathers constitute a protective coating by which, no doubt, many

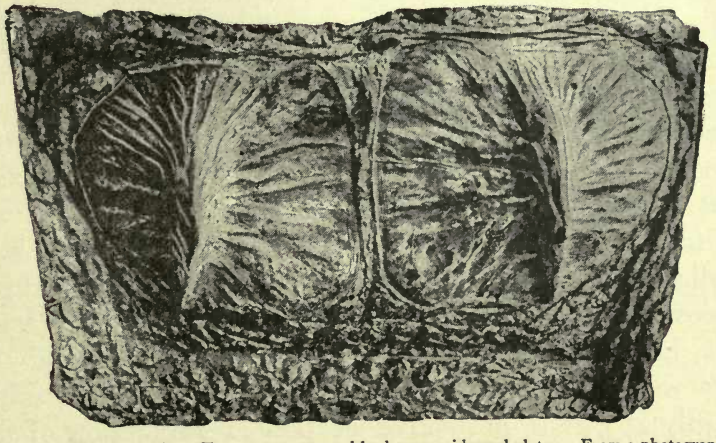


Fig. 491.—Nile Crocodile. Two scutes, covered by horny epidermal plates. From a photograph

bites and stings are prevented from taking effect upon the underlying skin, which is here unusually thin and delicate. Armoured Reptiles are common (fig. 490), Crocodilians (fig. 491) and Chelonians (turtles and tortoises) affording the best instances of protective plates, while one of the Australian Lizards (*Moloch horridus*)

will serve as an illustration of a spiny covering. The defences of tortoises and turtles have been already described (vol. i, p. 214), but it may be repeated here that such an animal is, as it were, enclosed in a firm box (fig. 492), mostly formed of an upper (carapace) and a lower (plastron) shield. Head, tail, and limbs can be more or less drawn back into the shelter thus afforded. The rear defences are strengthened by an ingenious device in the Hinged Tortoises of Africa. In these creatures the hinder part of the carapace is connected with the region in front of it by a sort of transverse hinge formed by an elastic ligament, so that when tail and hind-legs are drawn in, the movable part of the shell closes like a spring-door and protects these parts from attack.

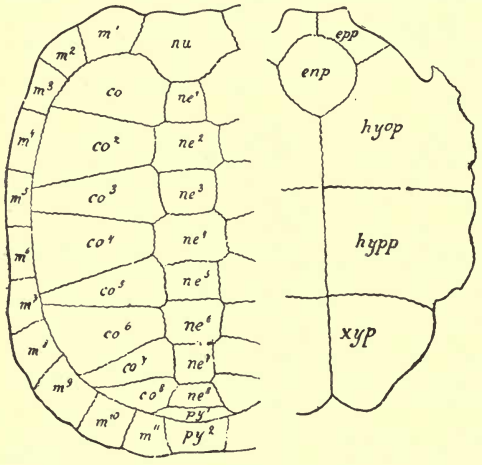


Fig. 492.—Carapace and Plastron of a Tortoise, from which the external horny plates have been removed

*ne*¹–*ne*⁸, Neural plates or broadened tops of vertebræ; *co*–*co*⁸, costal or rib plates; *nu*, nuchal or neck plate; *py*¹, *py*², pygidial or tail plates; *m*¹–*m*¹¹, marginal plates; *epp*, *hyop*, *hypp*, *xyp*, paired plates of plastron; *enp*, unpaired plate of plastron.

Armour is singularly deficient in recent Amphibians, but the members of one extinct order of these creatures (*Stegocephala*) were well off in this respect. A very extraordinary arrangement is found in two living species of newt, *i.e.* the Spanish Newt (*Triton Waltli*), and another form (*Tylototriton Andersoni*) native to the Loo-Choo Islands. These creatures possess long sharp ribs, which sooner or later penetrate the skin. Afterwards, as Gadow remarks (in *The Cambridge Natural History*), "the wounds heal up, the skin forming a neatly-finished-off hole through which the spike projects, not as a formidable, but as a sufficiently awkward, protective weapon". Protection of the kind is well developed in many Fishes. Good examples of firm plates are found in the Bony Pike (*Lepidosteus*), the Bichir of the Nile (*Polypterus*), and Coffer-Fishes (*Ostracion*). Short, strong spines abound on the Thornback Ray (*Raia clavata*), and the Globe-Fishes (*Diodon* and *Tetrodon*) are covered by more numerous and longer defences of the sort. In a large number of forms

sharp spines are connected with some of the fins, and as it is the dorsal ones which are best off in this respect, we may infer that such fishes are most likely to be attacked from above by enemies.

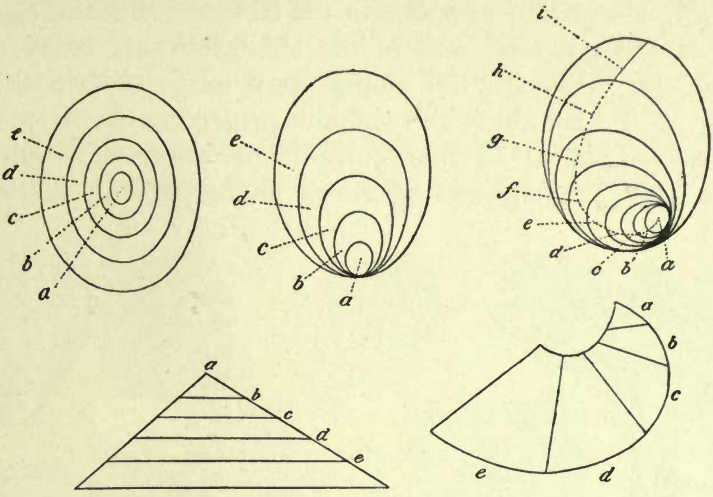


Fig. 493.—Method of growth in Gastropod Shells. The three upper figures show upper surface, while the two others are side views. *a*, *b*, *c*, *d*, *e*, represent successive additions to the shell.

Cat-Fishes (*Chimæra* and *Callorhynchus*), the Piked Dog-Fish (*Acanthias*), and Perch-like Fishes may be taken as examples.

Many of the Mollusca are more or less perfectly enclosed in shells, which receive successive additions as their owners increase in size, and these are usually indicated by *lines of growth* visible on the outer surface. The shape of a Gastropod varies in shape according to the way in which additions are made (fig. 493), and the same thing is also true of the shell of a bivalve. A shell of the latter kind is shown in section in fig. 494, and the various stages of its growth are indicated in a diagrammatic way.

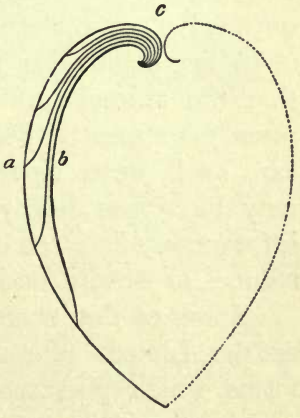


Fig. 494.—Growth of Bivalve Shell as seen in section. *c*, Oldest part; *a*, later additions; *b*, youngest layer represented.

Molluscan shells may be either of the nature of plate-armour, or may be provided with sharp projecting spines. Among the former are Pearly Nautilus (*Nautilus pompilius*), Garden Snail (*Helix aspersa*), and Freshwater Mussels (*Unio* and *Anodonta*).

Among the spiny Sea-Snails may be mentioned species of

the genus Murex (fig. 495), also Scorpion-Shells (*Pteroceras*), while Thorny Oysters (*Spondylus*) and the Spiny Cytherea (*Cytherea dione*) are good illustrations of spiny bivalves. It is particularly interesting to notice in the last case that the spines are massed at the posterior end of the shell, the part most exposed to attack, for, although the animal may bury itself in the loose covering of the sea-floor, the siphons projecting from its hinder-end must be placed so that currents of water may enter and leave (see p. 249) by the apertures there present, respectively

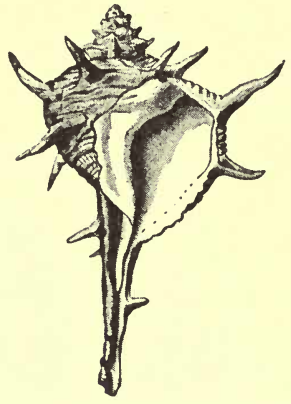


Fig. 495.—A spiny Sea-Snail (*Murex*)

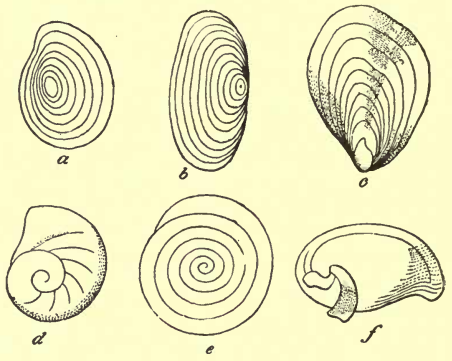


Fig. 496.—Opercula of various Gastropods.

a, River Snail (*Paludina*); *b*, Whelk (*Buccinum*); *c*, *Murex*; *d*, *Cyclostoma*; *e*, *Trochus*; *f*, *Nerita*.

carrying food and oxygen inwards, and waste products of all sorts outwards.

In many univalve Molluscs (*Gastropoda*) the shell is so roomy that the animal can withdraw entirely into it. Such a creature often possesses a special plate (operculum) by means of which it can, as it were, close the door behind it (fig. 496). This plate may be simply horny, as in a Whelk or Periwinkle, though not infrequently it is composed of dense shelly material, as, for instance, in Nerita and Neritina.

Some of the 'tween-tide Gastropods which live on rocks, such as the Limpet (*Patella*) (p. 197), are descended from ancestral forms which possessed a large spiral shell into which the body could be withdrawn. The conical structure by which this has been superseded is, however, a very efficient defence, for when alarmed a Limpet holds on with great force by means of its powerful foot, and pulls down the shell so that its edges touch the surrounding rock. To dislodge the animal from its hold

requires great force if it is once allowed to fix itself firmly although, if taken unawares, a smart tap is generally sufficient.

Jointed-limbed Invertebrates (*Arthropods*) are invested in a firm, horny external skeleton, sometimes thick enough to constitute veritable plate-armour, and not infrequently garnished with protective spines. Insects and Crustacea afford the best examples.

Insect Armour.—Beetles are often distinguished by the thickness of their integuments, and, as previously mentioned (see p.

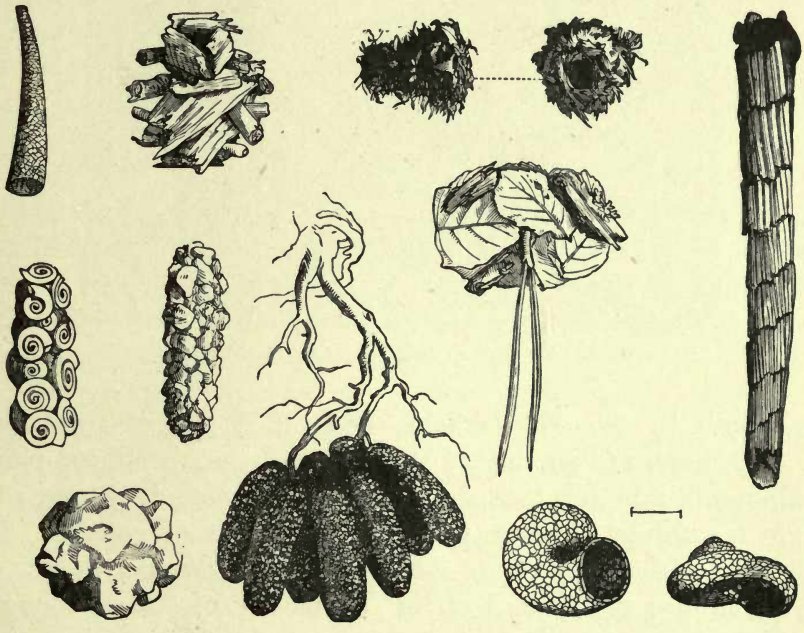


Fig. 497.—Caddis-Worm Tubes of various kinds (enlarged)

315), some of the weevils are so well off in this respect as to be avoided by insectivorous birds. Certain tropical beetles (of the genus *Hispa*) present a *chevaux-de-frise* of long, sharp-pointed spines.

The larvæ of Caddis-Flies, commonly known as "caddis-worms", make protective tubes by cementing together all sorts of available substances (fig. 497).

Crustacean Armour.—To illustrate the smooth variety of defensive armour-plating among Crustaceans, a better example could hardly be chosen than the common Edible Crab (*Cancer pagurus*). Here the greater part of the body is enclosed in

an extremely thick carapace, strengthened by the deposit of lime-salts, and the insignificant tail which, if left sticking out, would constitute a weak place in the defences, is kept tucked up out of harm's way into a depression on the under surface. The walking-legs, too, can be folded up under the body, and the great pincers brought together in front. The Northern Stone-Crab (*Lithodes maia*) (fig. 498), pleasingly termed the

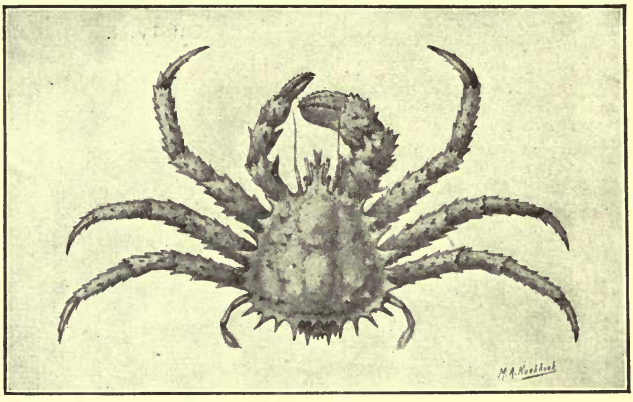


Fig. 498.—The Northern Stone-Crab (*Lithodes maia*), reduced

Devil-Crab by the Norwegians, and allied species from Japan and elsewhere, are so thickly covered with sharp spines, pincers, walking-legs and all, that they would undoubtedly prove rather trying mouthfuls to even the most sharp-set of enemies. The front part of the body of the Rock-Lobster (*Palinurus*) (see vol. i, p. 412) is also pretty well off in the matter of spines, though at first sight it seems odd that its large tail should be quite smooth, while part of the tail-fin is soft. The seeming anomaly is cleared up when we remember that this animal is in the habit of watching for prey with the smooth tail sheltered in a crevice, so that only the thorny part of the body is exposed to the attacks of more powerful creatures. Accommodation of armour to growth is effected in this group by a method differing entirely from the economical Molluscan plan. A Crustacean, in fact, undergoes a series of "moults" until the adult maximum size is reached, and these are very frequent in early life. At such times the entire hard covering of the body is cast off, and also the firm lining of the stomach (see vol. i, p. 407).

In free-living Bristle-Worms (*Chætopoda*) the bristles may be

sufficiently well-developed and numerous to constitute a means of defence, as, for instance, in the Sea-Mouse (*Aphrodite aculeata*) (p. 147) and the Porcupine Worm (*Hermione hystrix*). The tube-dwelling worms, which are closely allied to the preceding, construct habitations of the most varied kind, which may either (like the shells of Molluscs) be entirely secreted by their possessors, or may be made up of foreign bodies firmly cemented together. We may contrast the long parchment-like tube of Hyalinœcia with the curved or undulating calcareous tubes of Serpula (see p. 258) and its allies, and the spiral house of Spirorbis made up of similar material. In these forms, too, one of the tentacles carried on the head is converted into a stopper or operculum, by which the tube is closed when the animal is withdrawn. The most varied foreign bodies are used for tube-construction, nor are these necessarily associated in a haphazard manner. Of this matter Benham (in *The Cambridge Natural History*) says:—"But the process of tube-making is not a simple one, for in many cases, at least, the worms exhibit definite powers of choice. Thus some species of *Sabella* choose only the very finest particles of mud; *Terebella conchilega* chooses fragments of shell and grains of sand; *Onuphis conchilega* employes small stones more or less of a size; *Sabellaria* makes use only of sand grains. Whilst some worms, like *Terebella*, *Nichomache*, and others, make a very irregular tube, *Pectinaria* builds a most remarkably neat house, open at each end, which it carries about with it, the narrow end uppermost; the grains of sand are nearly all of the same size and only one layer in thickness, embedded in abundant 'mucus', and with the outer surface quite smooth."

Moss-Polypes (*Polyzoa*) are for the most part colonial animals, collectively forming a mass of the most varied shape, flattened ("sea-mats"), shrub-like, as encrustations on sea-weeds, &c. The members of the colony are invested by horny coverings, sometimes hardened by calcareous deposits, and each of them can be withdrawn into a little cup, which is in some cases closed by a lid or operculum. The defences of the colony may be strengthened by the addition of projecting spines.

Lamp-Shells (*Brachiopoda*) are enclosed in bivalve shells, but these are quite different in character from those possessed by bivalve molluscs, and are also differently placed in relation to the body (see vol. i, p. 439). Each valve is lined by a fold of skin

(mantle), and in nearly all cases the edge of this is provided with projecting bristles, which probably serve as a protection, though they may also constitute a sort of filter for sifting the inflowing currents of sea-water (set up by ciliary action) by which the animal gets its food and oxygen. The shells of some extinct lamp-shells were beset with spines.

Echinoderms are remarkable for the calcareous plates which are imbedded in the skin, and which are well seen, for instance, in the ordinary Star-Fishes, Brittle-Stars, and especially in Sea-

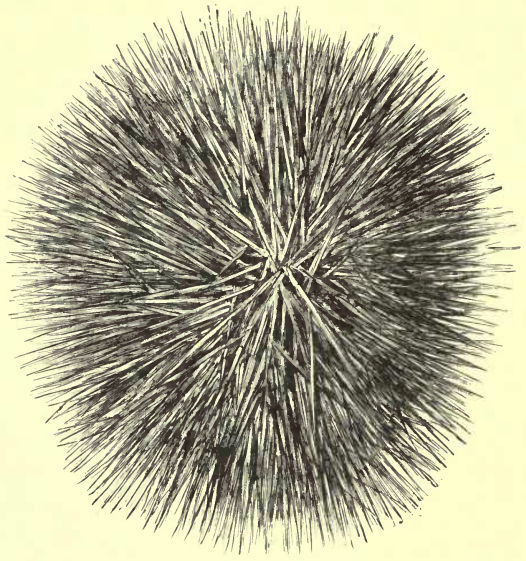


Fig. 499.—A Sea-Urchin (*Echinus lividus*), showing protective covering of spines

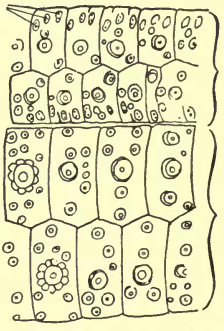


Fig. 500.—Part of Sea-Urchin test, showing knobs for attachment of spines.

Urchins, where they are united together in a very regular manner by their edges, to form a "test". Spines may also be present, and these are particularly well-developed in the Sea-Urchins (*Echinoids*) (figs. 499, 500), which have earned their ordinary name from this fact, for "urchin" is an old English word for hedgehog. In some of these forms the spines (which are not fixed, but united to the test by ball-and-socket joints) are so long and sharp as to constitute a defence of really formidable character.

Armoured Zoophytes (Cœlenterata).—Passive defence is not the chief means of defence in this group, which, however, presents many examples of it. The colonial branching Hydroid Zoophytes, so often mistaken for sea-weeds, are invested in horny coverings

much as in the Moss-Polypes, but only some species are provided with cups into which the individual members can be withdrawn, nor are such cups provided with lids. The Organ-pipe Coral (*Tubipora musica*) is another good instance. The colony is made up of a number of calcareous tubes (composed of fused spicules), one for each individual, and the members of the colony when alarmed draw themselves back into their tubes. A common British Sea-Anemone (*Tealia crassicornis*) gains protection by means of small stones which adhere to its sticky body. When the animal contracts, this stony covering not only forms a protection, but renders the creature very inconspicuous (see p. 289).

Armoured Sponges and Animalcules.—The bodies of most Sponges are traversed in all directions by sharp needles of lime or flint, some of which may project at the surface to form a *chevaux-de-frise.* Anyone who has incautiously handled such sponges can testify to the penetrating power of these structures (see vol. i. p. 485). As most persons are only familiar with the ordinary bath-sponges, it may not be superfluous to repeat what has elsewhere been said, that this particular kind does not possess spicules, its skeleton being merely a close network of fibres of horny consistency.

Among the Animalcules (*Protozoa*) protecting shells characterize the Foraminifera and Radiolaria (see vol. i, p. 489), and in the former they may be made up of foreign particles cemented together, though usually calcareous in nature. The shells of Radiolarians are commonly flinty, and in many cases possess radiating spines. Horny shells are present in some of the freshwater Rhizopods allied to the Proteus Animalcule (*Amœba*), and particles of sand are worked into such shells in certain species (e.g. *Difflugia*).

PASSIVE DEFENCE BY MEANS OF SPECIAL HABITS

There is no sharp boundary between this and defence by armour, for it often happens that such armour is only fully effective when disposed in a particular manner.

A very interesting case in point is what may be termed the ROLLING-UP HABIT, practised by animals of which only the upper sides are properly defended. In the Three-Banded Armadillo or Mataco (*Tolypeutes tricinctus*), for example, this can be done very

perfectly, the shape of the armour-covered head and tail enabling them to be snugly tucked away side by side. In the following passage Darwin (in *A Naturalist's Voyage*) speaks of it thus:— "It has the power of rolling itself into a perfect sphere, like one kind of English wood-louse. In this state it is safe from the attack of dogs; for the dog, not being able to take the whole in its mouth, tries to bite one side, and the ball slips away. The smooth, hard covering of the *mataco* offers a better defence than the sharp spines of the hedgehog." The scaly Pangolins of South Africa and South-East Asia practise the same tactics. Both the Common Porcupine (*Hystrix cristatus*) and the Common Hedgehog (*Erinaceus Europæus*) roll themselves up when threatened by enemies, the quills or spines being at the same time erected.

Among Primitive Molluscs the curious Mail-Shells (*Chiton*, &c.) are defenceless below, but are provided with eight protective plates above. These overlap in such a way as to form a complete investment when the animal rolls up, as it is in the habit of doing when alarmed. Two Arthropod examples will serve to further illustrate the same method of defence. One is that of the long since extinct Trilobites, rolled-up specimens of which are frequently found in the fossil condition. Some members of the group of land-crustaceans, popularly known as Wood-Lice, have earned the name of "Pill Bugs" from the fact that they practise this mode of defence, a common British species, the Pill Wood-Louse (*Armadillidium vulgare*), being a good illustration.

We now pass on to the consideration of habits not related to the effective use of defensive armour.

Death-feigning Habit.—Many carnivorous animals which pursue living prey will not condescend to touch dead bodies, and hence the fact that a number of forms, when suddenly attacked or hard pressed by their foes, pass into a state of "apparent death", may perhaps be explained as a defensive arrangement. Various views have been held regarding this phenomenon. Some believe it to be a deliberate action, an actual "feigning" of death, others suppose it to be a kind of paralysis induced by fright, while the suggestion has also been made that it is comparable to a state of trance or catalepsy induced by hypnotic (mesmeric) influence. It is not likely that the same explanation will apply in all cases, and the heading of this section is adopted solely for convenience, and does not express belief in the first way of explanation.

Many stories have been related regarding the death-feigning habit as exhibited by the Australian Dingo (*Canis dingo*), and it is so well exemplified by the Opossums of America, that "to play 'possum" has become a proverb. Hudson (in *The Naturalist in La Plata*) gives a description of the "death-simulating swoon" into which a species of South American Fox (*Canis azaræ*) (fig. 501) falls if caught in a trap or worried by dogs, and expresses it

Fig. 501.—A species of South American Fox (*Canis azaræ*)

as his opinion that the animal does not altogether lose consciousness, though, judging from the fact that it bears without flinching various cruelties practised upon it by gauchos, he also states:—"I can only believe that the fox, though not insensible, as its behaviour on being left to itself appears to prove, yet has its body thrown by extreme terror into that benumbed condition which simulates death, and during which it is unable to feel the tortures practised upon it". Some Birds also feign death when hard pressed, the Spotted Tinamou (*Nothura maculosa*) of the Pampas being given as an example by the author just quoted. Lloyd Morgan (in *Habit and Instinct*) quotes from Canon Atkinson an amusing description of death-feigning by Land-Rails and Water-Rails when caught. "A gentleman's dog catches a land-rail and brings it to his master, unhurt, of course, as is the well-trained dog's way, but to all appearance perfectly dead. The dog lays the bird down at his master's feet, and he turns it over with

his toe. It simply moves as it is moved, all its limbs limp. Continuing to regard it, however, the man sees an eye opened, and he takes it up. The 'artful dodger' is quite dead again in a moment, head hanging and dangling, limbs loose, and no sign of life anywhere. It is put in its captor's pocket, and, not liking the confinement, begins to struggle. When taken out it is just as lifeless as before; but being put down on the ground and left undisturbed—the gentleman having stepped to one side, but continuing to watch—it lifts its head in a minute or so, and, seeing all apparently serene, it starts up on a sudden and 'cuts its lucky' with singular speed."

"In the case of the water-rail which came under my own observation, it was picked up on a snowy day by the most intimate of the friends of my youth and early manhood. He assumed that it was dazed with cold, and perhaps what we Yorkshire folks call 'hungered' as well. So he brought it home with him, and laid it on a footstool in front of the dining-room fire. Five minutes passed—ten were gone—and still the lifeless bird lay as it was put down, dead to all seeming; only not stiff, as it ought to have been if dead of cold as well as hunger. A few minutes later, my friend, who was very still, but yet with an eye to the bird, saw it—not lift its head, like the land-rail, and take a view, but—start off in a moment with no previous intimation of its purpose, and begin to career about the room with incredible rapidity. It never attempted to fly. Any other captive bird in its position would have made for the window at once, and beaten itself half to pieces against the glass. Not so the rail. With it, in its helter-skelter and most erratic course, it was anywhere rather than the window or the fire. Round the room, across the room, under the sofa, under the table, from corner to corner, steering itself perfectly, notwithstanding legs of chairs, legs of tables, the sofa-feet, footstools, or what not, on and on it careered; and it was not without some patience and many attempts that it was eventually secured."

There are also some Reptiles which feign death when attacked, and a Lizard which illustrates this habit is described by Darwin (in *A Naturalist's Voyage*), when speaking of the fauna of Bahia Blanca on the Argentine coast:—"Of Lizards there were many kinds, but only one (*Proctotretus multimaculatus*) remarkable from its habits. It lives on the bare sand near the sea-coast, and from its mottled colour, the brownish scales being speckled with white, yellowish red, and dirty blue, can hardly be distinguished from

the surrounding surface. When frightened, it attempts to avoid discovery by feigning death, with outstretched legs, depressed body, and closed eyes. If further molested, it buries itself with great quickness in the loose sand. This Lizard, from its flattened body and short legs, cannot run quickly." Similar observations have been made as regards some Amphibians.

Spiders are notorious for the way in which they simulate death, drawing in their legs and remaining perfectly motionless until an opportunity of escape offers. The same habit is characteristic of many Beetles.

FECUNDITY OF ILL-DEFENDED ANIMALS

Many comparatively defenceless animals are extraordinary fertile, and this may be looked upon as a special means of defence for the species (which might otherwise become extinct), though it is of no service to the individual. A great many ill-defended forms, indeed, would seem to have as their chief function the furnishing of a food-supply to other animals. The astonishing fertility which compensates for such ravages has enabled many such weak creatures not only to hold their own, but actually to become the most abundant species on the face of the earth. The Rodents, among Mammals, furnish a good example of this. They are the most cosmopolitan of their class (with the possible exception of bats), and are represented by a very large number of species and an enormous number of individuals. Yet these creatures are mostly of small size, and are exposed to the attacks of innumerable enemies against which they are not particularly well defended. On the average, it may be said that the total number of individuals of any particular rodent remain fairly steady, *i.e.* the ravages of enemies prevents the rapid production from having any marked effect; but how largely such animals help to feed more powerful forms has been demonstrated by cases where, for some special reason, the toll levied upon them has been lessened. The Rabbit, for example, is proverbial for its rapid powers of increase, notwithstanding which its numbers in this country appear to remain much about the same from year to year. But when this same animal was introduced into Australia, a country comparatively free from predaceous forms, it multiplied with such enormous rapidity as to become a serious nuisance to mankind. In Europe all this

superfluous rabbit-flesh would have been used up as food by more powerful animals.

Insects again, as we have had occasion to learn, furnish food to a great variety of other animals, notwithstanding the large number of protective devices exhibited within the limits of their class. And it is only by means of immense powers of increase that the ravages of their enemies are made good; indeed so great are these powers, that there are more insects in the world than any other land animals. A single illustration will perhaps suffice (taken from Wallace's *Darwinism*). Speaking of the rapid increase of organisms this author says:—"In the lower orders this increase is particularly rapid, a single flesh-fly (*Musca carnaria*) producing 20,000 larvæ, and these growing so quickly that they reach their full size in five days; hence the great Swedish naturalist, Linnæus, asserted that a dead horse would be devoured by three of these flies as quickly as by a lion. Each of these larvæ remains in the pupa state about five or six days, so that each parent fly may be increased ten thousand-fold in a fortnight. Supposing they went on increasing at this rate during only three months of summer, there would result one hundred millions of millions of millions for each fly at the commencement of the summer—a number greater, probably, than exists at any one time in the whole world. And this is only one species, while there are thousands of other species increasing also at an enormous rate; so that, if they were unchecked, the whole atmosphere would be dense with flies, and all animal food and much of animal life would be destroyed by them." The following example will serve to show how the numbers of a particular species may be kept down by even a single kind of enemy.

"During a very cold winter in the district of Hanau several thousand old oaks were cut down, in the hollow trunks of which many tens of thousands of bats sheltered during the rigorous part of the year. As the trees were felled and sawn into pieces most of these useful animals perished, either of cold or maltreatment at the hands of boys. In the following year much larger numbers than usual were seen of the Oak Procession-Moth (*Cnethocampa processionea*), and for a number of years after the caterpillars of this moth became a most destructive pest in the Hanau district, over an area of miles in circumference. Not only were oaks stripped of leaves, but also a large number of other forest trees

as well as fruit trees. Before this time procession caterpillars were not wanting from the Hanau district, but the large number of bats flying about in the night had caught and devoured so many moths that great increase of this pest was prevented. When almost all the bats in the district had been destroyed, a great caterpillar infestation could not be avoided, the insect being freed from almost all its enemies. For the mature winged stage is of nocturnal habit, and exposed only to the attacks of bats and goatsuckers, the latter never being present in more than limited numbers. The caterpillars are so well protected with hairs that scarcely anything but cuckoos can devour them, and the chrysalides are sheltered by a thick cocoon from the attacks of most enemies. The eggs alone are largely eaten during the winter by gipsy migrants (tits, tree-creepers, nuthatches, &c.). The procession-moth, in fact, has always so few enemies, that it invariably increases largely in numbers if the chief of them happens to be rapidly exterminated." (Extracted from Gloger, by Ritzema Bos, in *Animal Friends and Foes.*)

CHAPTER XXIX

ANIMAL DEFENCES—ACTIVE DEFENCE

Passive Defence having now been pretty fully considered, we may pass on to Active Defence, remembering at the same time that this may be preceded or followed by retreat.

ACTIVE DEFENCE AGAINST ENEMIES

For this purpose either ordinary Aggressive Weapons may be used, or else those special structures to which the name of Actively Defensive Weapons is applicable, and these may be parts of the body which are commonly employed for other purposes.

AGGRESSIVE WEAPONS IN DEFENCE

The possibility here suggested is so very obvious that there is no need to say very much about it. A carnivorous Mammal, *e.g.* a Leopard, depends upon teeth and claws for capture and immolation of its prey, but it is clear that these same weapons are just as valuable for purposes of self-defence, if the occasion should arise. This it is pretty sure to do, for aggressive forms have numerous enemies, just as well as the more peaceful vegetarians. The beak and talons of a bird of prey, the formidable teeth of a crocodile, the poison-fangs of a venomous snake, the sting of a scorpion, the strong jaws of a tiger-beetle, and the stinging-cells of a jelly-fish will serve as further instances of aggressive weapons which may be of equal use for defensive purposes.

ACTIVELY DEFENSIVE WEAPONS

Actively Defensive Weapons of Mammals. — Apes and Monkeys, especially the larger species, defend themselves very effectively with their teeth, the canines of the male often being

in the form of large tusks. The large man-like apes, when driven to bay, prove formidable antagonists to man himself, and once grasped by their powerful limbs the sequel is apt to be disagreeable. Wallace (in *The Malay Archipelago*) thus describes the result of an attack by some of the Dyaks of Borneo upon a Mias or Orang-utan:—"A few miles down the river there is a Dyak house, and the inhabitants saw a large Orang feeding on the young shoots of a palm by the river-side. On being alarmed he retreated towards the jungle which was close by, and a number of the men, armed with spears and choppers, ran out to intercept him. The man who was in front tried to run his spear through the animal's body, but the Mias seized it in his hands, and in an instant got hold of the man's arm, which he seized in his mouth, making his teeth meet in the flesh above the elbow, which he tore and lacerated in a dreadful manner. Had not the others been close behind, the man would have been more seriously injured, if not killed, as he was quite powerless; but they soon destroyed the creature with their spears and choppers. The man remained ill for a long time, and never fully recovered the use of his arm." The Chimpanzee and Gorilla of tropical Africa would appear to be equally formidable when driven to defend themselves, though many exaggerations are current, largely based, no doubt, upon the accounts given by natives.

Some of the social monkeys combine for the purpose of defence, and may even resort to the use of missiles, an often-described case being that of certain Baboons, which, when hard pressed among the rocks, hurl down stones among the intruders.

The formidable tusks which are constituted by the upper incisors of the Walrus form no mean weapons of defence, but this is apparently their least important use. These animals mainly employ them in digging up the bivalve molluscs, &c., which serve as their food, and also to assist in progression on ice or land. They figure besides in those furious fights between the males which form a regular episode in the season of courtship, and this particular use for weapons is one of which many examples can be given, especially noteworthy being cases where, as, *e.g.*, in most deer, the male only is provided with structures suitable for such a purpose. More will be said about this elsewhere.

Elephants are so powerful that they are pretty free from the attacks of other animals, man only excepted, nor do they court

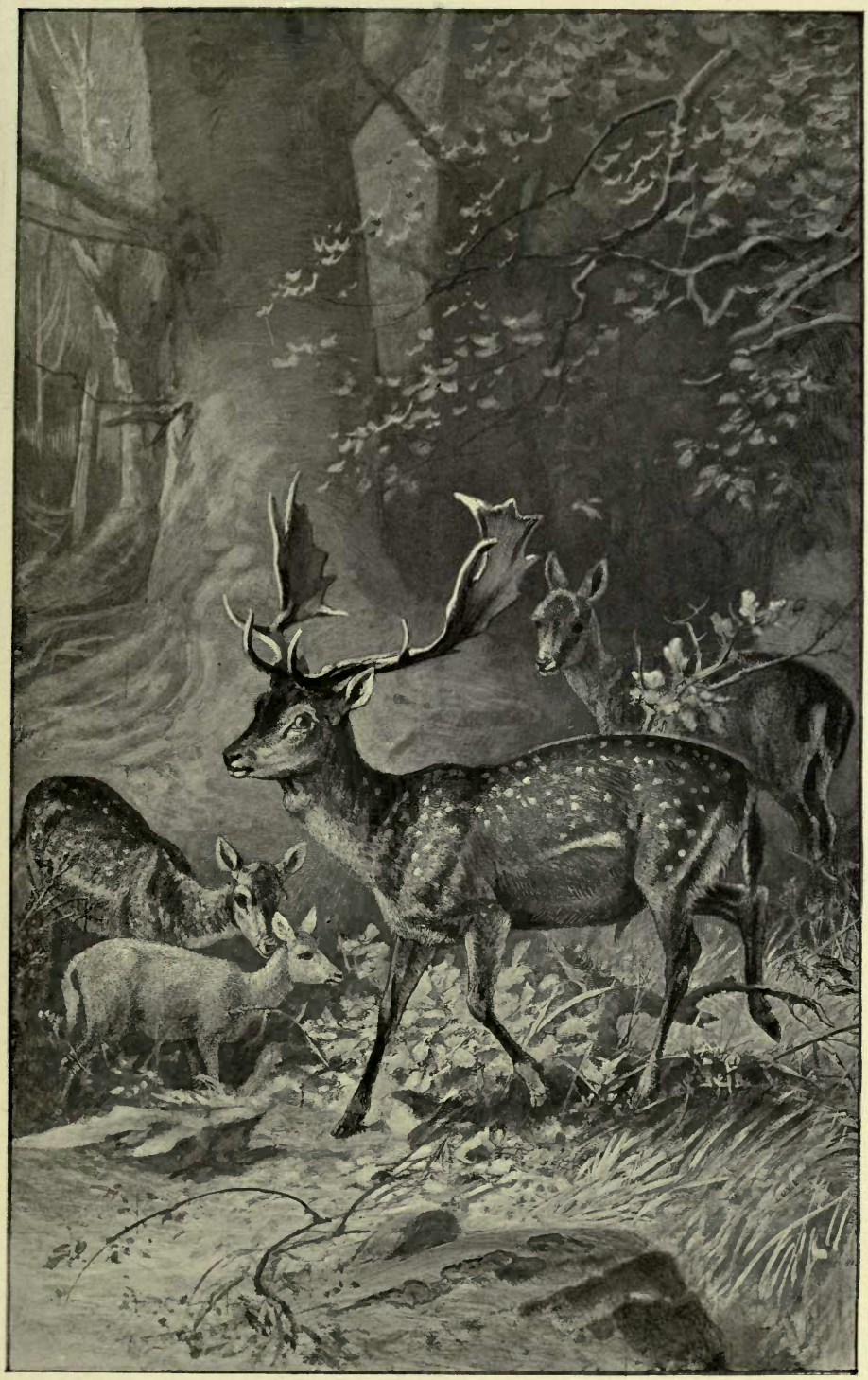
attack. When obliged to fight, however, their tusks are pretty nearly as useful as those of the walrus, being, however, of different nature, *i.e.* they are not canines but huge incisors, and continue to grow through life. The powerful trunk is also used in defence, and many a tiger has found to his cost that to be stepped or knelt upon by an elephant is a serious matter.

The different species of Rhinoceros are as well if not better defended than the elephant, but in an entirely different manner. The chief weapons of the African forms are the two sharp horns, which are entirely epidermal in nature. Of these the front and longer one is carried on the nasal region, and the other one farther back. The common Indian Rhinoceros has only one horn, corresponding to the first of these, though it is by no means so formidable as a weapon, this being fully compensated, however, by the presence of two sharp tusks in the lower jaw, which are used like the tusks of a wild boar. Many accounts have been given of the ferocity of rhinoceroses, but the balance of evidence appears to show that they are, for the most part, only dangerous when hard pressed by enemies and thoroughly aroused. The different species, however, and different individuals of the same species, would appear to differ greatly in this matter.

Horses and their allies fall next to be considered, and in these the first instinct appears to be retreat, though when forced to defend themselves they are able not infrequently to discomfit their enemies by vigorous kicks, the formidable nature of which is greatly enhanced by the hard hoofs, structures whose primary use is related to swift locomotion. The powerful teeth are also employed against some of their enemies. The following quotation from Vogt (*Natural History of Mammals*) regarding wild horses, illustrates combination for defence on the part of social animals:—

"The herds live under the leadership of some old males, which have to watch over the well-being of their subjects. We cannot but admire the courage of these proud creatures, which, seeming to rejoice in battle, dart down upon an attacking carnivore, the whole herd arranging itself in a circle with the foals in the middle, and all ready to strike with the hoofs of their hind-legs. In fighting with wolves, stallions try to seize their antagonists with their teeth by the nape of the neck, then to lift them up and dash them to the ground, after which they trample them underneath their feet. But these battles, from which perhaps the military

UNIV. OF
CALIFORNIA



THE FALLOW DEER (DAMA VULGARIS)

DRAWN FROM THE LIFE BY F. SPECHT

UNIV. OF
CALIFORNIA

art has derived the formation of squares, are only exceptions to the rule, and take place only in cases of sudden attack or when the herds are driven to straits. Usually the herd seeks its safety in rapid flight. Tearing along in furious gallop, with ears and mane erect, the herd dashes away with the speed of the wind, driving their young ones before them, the males galloping on the flanks and at the end of the column to protect the herd in its hurried flight." The military square, however, does not seem to have been copied from the horse. It is believed to have been invented by Sir William Wallace, who arranged his pikemen in serried circles to resist the onslaughts of the English knights at the battle of Falkirk. The squaring of these circles, if the expression may be permitted, was a further stage in evolution.

Man is the only serious enemy of the Hippopotamus, which is an animal of peaceable disposition except when attacked, but is then very formidable on account of its immense strength, backed by an armoury of tusk-like incisors and canines. Most Swine rely for defence on their upwardly-directed tusk-like canines, which are kept sharp by constantly rubbing against one another, and are particularly well developed in the male. These creatures are naturally peaceable, but when brought to bay, thrusts from their sharp tusks, given laterally or else from below, are capable of ripping up most antagonists. The little Peccaries of South America defend themselves by biting, as their canines, though sharp, are small, and not adapted for thrusting, the upper ones also being turned downwards, as is usually the case among Mammals. They live in large herds, and co-operate for defence against enemies, man included.

Most Ruminants are provided with defensive weapons in the form either of antlers or horns. Antlers, characteristic of deer, are bony outgrowths usually possessed by the male only, and shed annually. Although the two last facts are enough to prove that the primary object of these structures is not defence, their hardness and sharpness nevertheless makes them very effective for this purpose. Sir Samuel Baker (in *Wild Beasts and their Ways*) describes as follows the way in which on one occasion, in Ceylon, an Axis or Spotted Deer (*Cervus axis*) defended himself:—" I saw Killbuck reach the flank, but before he had time to make a spring, the stag threw his head upon one side, and backwards, so as to strike the dog with the extreme points of his long antlers. A

short time after, the stag came to bay upon firm open ground, and fought the dog face to face. I saw Killbuck rush straight at the deer's face, and instead of receiving the attack passively, the deer quickly lowered his head, and not only met, but charged, the dog, rolling him over, and following him up as he drove his sharp tines deep into his body."

The horns of Antelopes (fig. 502), Oxen, Sheep, and Goats, are quite different from antlers, and have earned for these creatures the name of "hollow-horned" Ruminants (*Cavicornia*). Many female antelopes do not possess them, but in some species of that group, and in the other animals mentioned, they are present in both sexes, though always more powerful in the male. The hornless or "polled" condition of certain races of cattle, sheep, and goats is a result of domestication. The horns of these various creature are epidermal structures, and consist of unbranched hollow sheaths composed of the material indicated by their name, supported by "horn cores", which are conical bony outgrowths from the skull. Unlike antlers they are never shed. Goats and Sheep defend themselves by butting with their horns; Oxen, Buffaloes, &c., and at any rate some of the Antelopes, use them for stabbing, or goring, to employ the word more specially applicable.

Horns commonly extend so far to the side, as in buffaloes, or to the back, as in many antelopes, that they can only be used for side-thrusts, which, however, may be very effective. Both in African and Indian Buffaloes (in which latter the horns sometimes exceed 12 feet from tip to tip) part of the defensive tactics consists in trying to force the enemy to the ground, either by "charging" or "tossing" him. Should this move be successful, a combination of goring and trampling generally polishes off the assailant.

The Sable Antelope (*Hippotragus niger*) is one of the most powerful of his kind, the backwardly-curved horns being often quite 3½ feet long in the male, though somewhat shorter in the female. When attacked, this animal is said to lie down, apparently inviting attack from behind. By lateral movements of the head the horns can then be swept over the back, transfixing any foe that has been rash enough to attack that part of the body. Selous says:—"The sable antelope is often very savage when wounded, and, like the roan antelope and gemsbok, will commit terrible havoc among a pack of dogs. Indeed, I have known one to kill

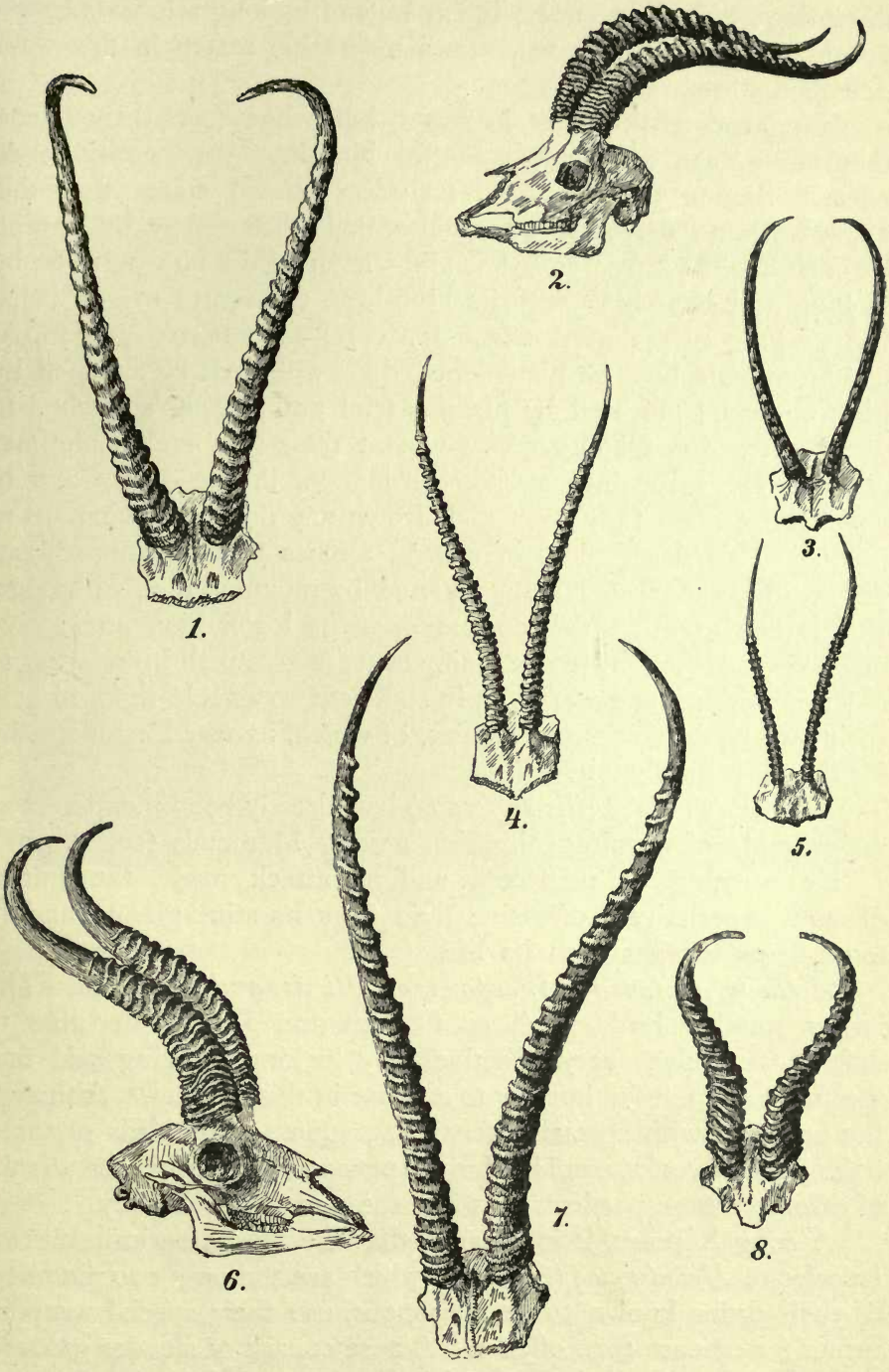


Fig. 502.—Horns of Gazelles

1, *Gazella Sæmmeringi*, male; 2, *G. dorcas*, male; 3, *G. dorcas*, female; 4, *G. Cuvieri*, male; 5, *G. Cuvieri*, female; 6, *G. Arabica*, male; 7, *G. Granti*, male; 8, *G. euchore*, male.

three dogs with three successive sweeps of its long scimitar-shaped horns." Even the lion sometimes meets his match in this well-defended form.

Kangaroos seek safety in flight, but when forced to defend themselves, can use their powerful hind-legs with considerable effect. Semon (in *In the Australian Bush*) states that this animal, when "driven to bay, will seek its last refuge by leaning its back against a tree and defending itself against its pursuers by kicking and scratching with its hind-legs, the fourth toe of which bears a long and pointed claw. On carelessly approaching an old kangaroo male bent on his defence, dogs will often be clutched by his fore-legs, suffocated by his powerful embrace, or scratched to death. . . . Some kangaroos, when at their wits' end, sometimes manage to escape into a river or lagoon, in the deep water of which they stand fully erect and drown any dog swimming up to them." This description, of course, applies to the artificial conditions of a kangaroo hunt conducted by mounted men with dogs. But it is clear that the powers of swift locomotion and active defence possessed by these animals were evolved in relation to older conditions, and were amply sufficient to enable them to hold their own against natural enemies, of which, as usual, man was by far the most formidable.

The Skunk (*Mephitis suffocans*) has already been mentioned as an example of warning-coloration among Mammals (see p. 301). If the warning be neglected and an attack made, the animal ejects a superlatively offensive fluid from its stink-glands, and in most cases escapes with its life.

Actively Defensive Weapons of Birds and Reptiles.—The larger running birds, such as Ostrich and Emeu, are able to defend themselves very effectively by kicking, it being said that the former is not far inferior to a horse in this respect. Although not provided with special defensive weapons, many birds of social habit, such as rooks, combine for the purpose of repelling the attacks of enemies, more particularly when these are birds of prey.

Among Reptiles, it is possible that the two American Lizards (species of *Heloderma*) (fig. 503), which are the only two members of their order known to be poisonous, use their special weapons rather for defence than offence. These consist of slender grooved teeth loosely attached to the jaw, and resembling the fangs of venomous snakes. At the base of each tooth is a small poison-

gland, the secretion of which is fatal to small mammals, and sufficiently virulent to be dangerous even to human beings.

Actively Defensive Weapons of Amphibia and Fishes.—Regarding Amphibians, it need only be stated here that the poison-glands in the skin, already spoken about (see p. 304), are in many

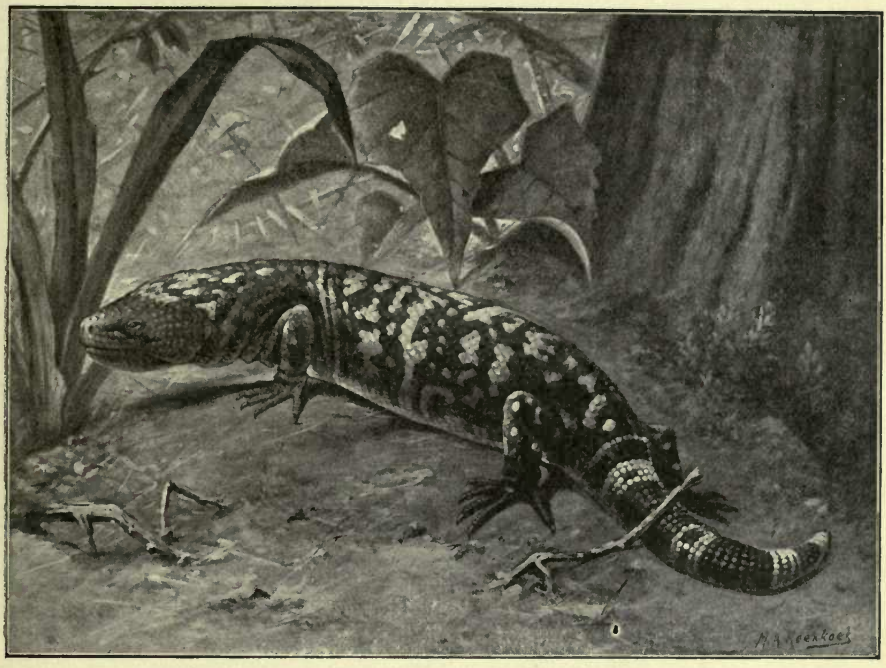


Fig. 503.—Poisonous Mexican Lizard (*Heloderma horridum*)

cases sufficiently potent to deserve mention under active defences as well as under passive.

Fishes are not infrequently provided with poison-spines (fig. 504) of varying degrees of complexity in structure, but all serving the purpose of defence. The most remarkable examples are found among some of the ordinary bony forms (*Teleostei*). The most elaborate case is that presented by certain small ground-fishes (species of *Thalassophryne*) from the coasts of Central America. These creatures possess four sharp spines, two on the back and one on each gill-cover or operculum. Each of these spines is constructed on the same plan as the poison-fang of a viper, being traversed by a canal which is open at the base and also on one side near the tip, an arrangement which prevents blockage when in use, just as in the needle of a hypodermic syringe. A

small poison-bag is situated at the base of each spine, and should some other animal blunder against the sharp point of this, the pressure causes the venom to be ejected into the wound. An equally if not more effective arrangement is possessed by some fishes (species of *Synanceia*) from the tropical parts of the Indian

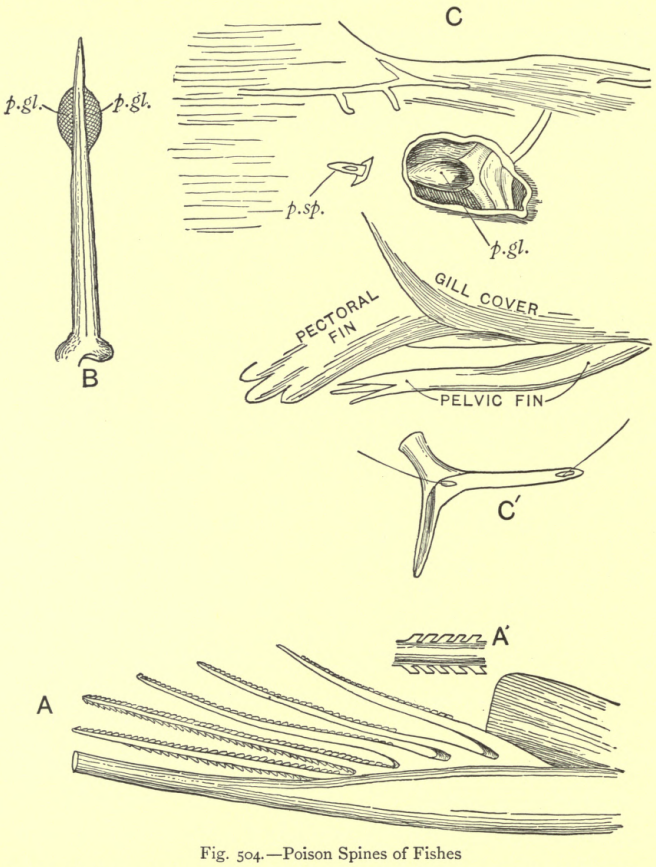


Fig. 504.—Poison Spines of Fishes

A, Spines on tail of an Eagle-Ray (Aëtobatis) (part of one drawn on larger scale at A′). B, Dorsal spine of *Synanceia*; *p.gl.* poison-bags; C, Side view of gill-cover in *Thalassophryne*: *p.sp* projecting tip of spine; *p.gl.* poison-bag (exposed by dissection). C′, Spine isolated, the projecting tip on right and bristle placed in canal.

and Pacific oceans. Here there is a series of sharp dorsal spines, of which the extremities are grooved at the sides, a small poison-bag lying in each groove. Of these fishes Günther (in *The Study of Fishes*) says:—"The native fishermen, well acquainted with the dangerous nature of these fishes, carefully avoid landing them; but it often happens that persons wading with naked feet in the sea, step upon the fish, which generally lies hidden in the sand. One or more of the erected spines penetrate the skin, and the poison

is injected into the wound by the pressure of the foot on the poison-bags. Death has not rarely been the result." Two of our native sea-fishes, the Greater and Lesser Weevers (*Trachinus draco* and *T. vipera*) are poisonous to a less extent, being provided with grooved spines on the back and operculum. There are here no poison-bags, but the slime which covers the spines has venomous properties.

Among Elasmobranchs, the Sting-Rays (*Trygonidæ*) and Eagle-Rays (*Myliobatidæ*) commonly possess one or more saw-edged spines on the tail, by the lashing movements of which they can be used to inflict jagged wounds, these injuries being at the same time rendered more dangerous by the poisonous nature of the slime which covers the spines. The range of one species, the Common Sting-Ray (*Trygon pastinaca*), includes the south coast of England.

Actively Defensive Weapons of Mollusca.—In the tropical Cone-Shells the horny ribbon of the rasping organ bears barbed teeth, upon each of which a poison-gland opens (p. 97). The living animal requires careful handling, for it promptly makes use of its means of defence. Another arrangement is found in some of those Sea-Slugs (species of *Æolis*) in which a number of club-shaped outgrowths (*cerata*) spring from the back, for these structures are armed with stinging-cells much like those characteristic of jelly-fishes, sea-anemones, &c.

In some of the large Bivalve Molluscs the mere closing of the shell constitutes a defence which may prove fatal to an attacking animal. A good example of this is given by Semon (in *In the Australian Bush*), where, in speaking of the natural history of Torres Straits, he says:—"A certain precaution has to be observed when collecting on the reefs. In the shallow water lie, their sides unfolded, the gigantic Tridacna-shells, such as are sometimes used in Europe as a font for holy water in Catholic churches, or as ornaments in halls and gardens. Woe to him who, in wading through the water, carelessly touches one of them. Many a searcher of tripang has met with this accident, and has had his foot cut through to the bone by the shells, which shut up with enormous force. No human power can open the shell, and a man thus caught can only be relieved by his companions cutting the adductor muscles of the shell with a knife."

Actively Defensive Weapons of Insects.—The most formidable structure calling for description here is the *sting* with which the

tip of the abdomen is provided in bees, wasps, and ants. This weapon may be used in some cases more for offence than defence, as in those digging wasps (see p. 106) which lay up a store of spiders or insects for the benefit of their larvæ, but in ordinary bees its chief use would appear to be that of defence. The hard parts of a Bee's sting (fig. 505) consist of three rods, of which one acts as a "director", along which the other two can be moved backwards and forwards, each of them presenting a longitudinal groove which works along a corresponding ridge. Each of these two "piercers" is a kind of flattened stylet, the tip of which is studded with a number of barbs. There are two poison-glands secreting respectively an acid and an alkaline secretion, and opening into a bladder-like sac. This in its turn pours its fluid into a sort of reservoir formed within a swelling at the base of the director, and thence it is conducted to the wound along a channel between the director and the two piercers, each of the latter possessing a projection which acts as a piston. It is well known that when a bee uses its sting, the piercers, being barbed at their tips, cannot be withdrawn, and are left sticking in the wound, while the attempt to withdraw them commonly proves fatal to their possessor. The sacrifice of the individual, however, benefits the species, for insectivorous animals commonly avoid bees (see p. 307). Female Wasps and Ants possess weapons of similar character, but the piercing stylets are not barbed, and can therefore easily be withdrawn, so that the individual is not liable to perish for the benefit of its kind.

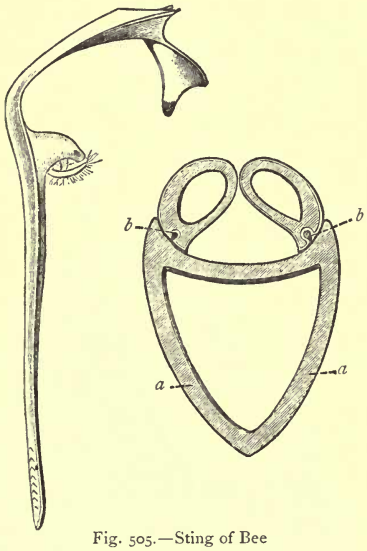


Fig. 505.—Sting of Bee

On the left one of the piercers is shown in side view, much enlarged. On the right a cross section through the sting, very highly magnified: *a a*, the director, on the upper side of which are two ridges, *b b*, along which the two piercers slide.

Insects not uncommonly possess variously-situated glands that secrete an offensive, or it may be acid, fluid, by the sudden ejection of which enemies may be discomfited. A well-known instance is that of the Bombardier-Beetle (*Brachinus crepitans*), which is provided with glands connected with the last part of the intestine (*rectum*). These secrete a volatile fluid which can be suddenly

ejected with a slight noise, giving at the same time the appearance of a minute puff of smoke. One of the little Click-Beetles (*Lacon murinus*), of which the larva attacks corn-crop, is provided with a pair of stink-glands, which open near the tip of the abdomen and secrete an extremely-offensive fluid. The protection afforded would appear to be considerable, for it is stated on good authority that when attacked this beetle makes no attempt to escape, but is content with assailing the nose of the enemy with evil smells. In the Mole-Cricket (*Gryllotalpa campestris*) there are stink-glands in much the same position as in the Bombardier-Beetle, and glands of similar kind open on the upper side of the abdomen in Earwigs. The order of Bugs (*Hemiptera*) has been much neglected, even by specialists, and this is no doubt partly due to the fact that very many of them, especially the plant-feeding forms, are provided with stink-glands, of which the secretion is decidedly offensive. It is a curious fact that in many such species the young are provided with glands of the kind which open on the upper side of the abdomen, but these are replaced in the adult by similarly-endowed structures opening on the sides of the thorax. The larval glands would not be of much use if retained, for their openings would be covered over by the wings.

The Stick-Insects (*Phasmidæ*) are provided with defensive glands in the thorax, of which the secretion is reputed to be extremely acrid as well as malodorous. It can be ejected with considerable force, and it is stated that blindness may result should it happen to get into the eye (compare p. 303). The caterpillar of the Puss Moth (*Cerura vinula*) is one of the forms which assume a terrifying attitude (see p. 313), and to this mode of defence is added the one now under consideration. Lodged in the front part of the body there is a gland secreting an irritant fluid containing as much as 40 per cent of formic acid, and this can be squirted out upon an attacking enemy, proving most effective when it happens to hit the eye. Poulton (in *The Colours of Animals*) speaks as follows of this secretion and its properties:—"So far as we know at present, no other animal secretes a fluid containing anything which approaches this percentage [40] of strong acid. . . . The value of this strongly-irritant liquid is sufficiently obvious. I have seen a marmoset and a lizard affected by it, and have myself twice experienced sharp pain as the result of receiving a very small quantity in the

eye. Although the secretion is therefore useful as a defence against vertebrate enemies, it is probably chiefly directed against ichneumons." As regards the latter point, it is known that this larva is very liable to the attacks of a particular species of ichneumon-fly (*Paniscus cephalotes*), which lays her eggs upon its skin. The larvæ which hatch out from these use the unfortunate caterpillar as a food-supply. Experiment has shown that the acid secretion is either immediately fatal or else highly injurious to ichneumons upon which it happens to fall.

The hairs which clothe many caterpillars produce a highly irritating effect upon the mouths of insectivorous animals (or the fingers of human beings), and this is partly the result of their being barbed, besides which they are probably endowed with poisonous properties, like the spines of certain fishes (see p. 355). Such aggressive hairiness is associated with warning-coloration (see p. 301). A typical example is that of the Palmer Worm, which is the larva of the Gold-tail Moth (*Porthesia auriflua*), and is rendered conspicuous by its markings of white spots and red lines upon a black ground. The barbed hairs are not the only disagreeable point about this caterpillar, for it also possesses defence-glands opening on the upper surface of the body, and secreting an acrid fluid.

Actively Defensive Weapons of Myriapods and Peripatus.—Centipedes would appear to be sufficiently defended by the possession of poison-jaws, primarily weapons of offence. Millipedes, however, are non-aggressive vegetarian creatures devoid of such structures, and repel the attacks of their enemies by means of numerous stink-glands, which open on the sides of the body and secrete an offensively-smelling fluid containing prussic acid.

The slime-glands of *Peripatus*, which open on two papillæ near the mouth, would appear to be special means of defence, though, in the New Zealand species at any rate, they are also employed in the capture of prey. Speaking of the Cape species Sedgwick says (in *The Cambridge Natural History*):—"They will turn their heads to any part of the body which is being irritated and violently discharge their slime at the offending object".

Actively-Defensive Weapons of Lower Invertebrates.—The numerous and often powerful setæ with which many of the marine Bristle-Worms are provided would seem, in some instances at least, to serve for active as well as passive defence, though there

is an absence of observations on the subject. At any rate, many of them are extremely sharp-pointed, and often serrated in such a way as to render their possessor a somewhat unpleasant morsel of food.

Many of the Planarian Worms, when irritated, discharge large numbers of microscopic rods (*rhabdites*) from the skin, and it is likely that these possess irritant properties. Some few members of the same group are also provided with stinging- or nettling-cells, much like those of sea-anemones, jelly-fish, and similar creatures, and these are undoubtedly defensive structures.

Among Echinoderms we find that some of the Sea-Urchins are provided with poison-spines (fig. 506), reminiscent of what has been described for certain fishes (see p. 355). Such a spine has a swollen end in which a poison-bag is lodged, this communicating with an excessively-sharp perforated style, by which the wound is inflicted and poison introduced into it.

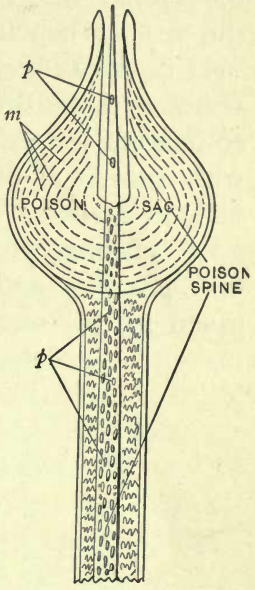


Fig. 506.—Poison-spine of a Sea-Urchin (*Asthenosoma urens*) in longitudinal section: *p*, *p*, holes in side of the hollow spine; *m*, layers of muscle. Diagrammatic and enlarg

The innumerable nettling- or stinging-cells with which the members of the great phylum Cœlenterata (jelly-fishes, sea-anemones, corals, &c.) are provided undoubtedly serve as actively-defensive weapons, though perhaps it is right to primarily regard them as means whereby active prey is paralysed and secured (see p. 158). The brightly-coloured Sea-Anemones are richly endowed with these protective structures, and it is a matter of observation that most fishes leave them severely alone. Probably the vivid hues which they flaunt are to be looked upon as examples of "warning-coloration", and the same thing is very likely true for Corals. But, as already remarked, every means of defence is more or less met by counter devices among aggressive forms, and to some of the coral-reef fishes the stinging-cells have no terrors. The Parrot-Fish (*Scarus*), for instance, browses upon corals, the hard parts of which are effectively tackled by its firm parrot-like jaws, while the stinging-cells are not able to injure the hard lining of its mouth.

The Slipper-Animalcule (*Paramœcium*) is a good example of

a defensive arrangement found among a number of the higher Protozoa. The outer layer of this creature's body is packed with innumerable rod-like bodies (*trichocysts*), which can be shot out when their owner is irritated, much like the rods in the skin of some Planarian Worms, and the rods would appear to possess irritant properties. It must be remarked, however, that after these structures have been brought into play their possessor dies, breaking up into a number of pieces; so that, as in the case of the Honey-Bee (see p. 358), the arrangement is one by which the species benefits at the expense of the individual.

Co-operation for Active Defence among Social Animals.—Some of the herbivorous Mammals which live in communities co-operate for defence in a very skilful manner, though, to begin with, retreat is usually the first proceeding, and it is only when obliged to make a stand that they turn upon their enemies. A good instance, that of Wild Horses, has already been quoted (see p. 350), and space prevents further examples from being given in this section.

CHAPTER XXX

ANIMAL DEFENCES—RETREAT

Having now considered Active and Passive Defence at considerable length, it only remains to speak of that method which has been described as a "strategic movement to the rear", in order to make the section complete.

Animals which are subject to the attacks of powerful enemies often possess very considerable powers of locomotion, and in such cases retreat is usually the first instinct acted upon, though it not infrequently happens that such creatures, when actually driven to bay, are able to give a very good account of themselves. It is recognized that in human warfare a successful retreat is the most difficult of all tasks to perform, though in this case both sides are fully provided with aggressive weapons, and innumerable devices are adopted to baffle the pursuing enemy. Ingenious methods answering the same end are by no means unknown among animals, and several of them will be mentioned in their proper place.

Retreat among Mammals.—As might be expected, the more intelligent Monkeys display a good deal of method in the way they effect a retreat, some of those which live in troops placing sentinels before they begin their plunder of a native crop, and when alarmed retiring in good order, taking every advantage of cover.

Vogt (in *Mammalia*) gives the following lively account of the mode of life among Baboons (fig. 507), which shows how carefully arrangements are made by such creatures for retreat when alarmed:—"So far as our information goes, it would seem that all baboons live mostly in considerable troops, often numbering several hundred, and in these there are always several old males and females, so that the leadership does not, as among most other monkeys, fall to a single patriarch. . . . The troop passes the night in caves in the rock, and in grottoes in inaccessible precipices, all closely huddled together, and at sunrise

Fig. 507.—Baboons retreating from Wild Dogs

they slowly and deliberately quit their retreat in search of food. Large stones are often overturned by their united efforts in order to seek for any animals that may have crawled under them, such animals forming, along with roots, tubers, juicy leaves, and fruits, their chief nourishment. After that the company bask in the sun with their backs turned to the wind, the older ones sitting on stones, while the young tumble and play about. The old, meanwhile, keep a careful watch all round; the troop next go to some water to drink, and after supper they betake themselves once more to rest. For the most part a troop sticks to the same feeding-ground, for some time at least, but from time to time it changes its ground.

"On the approach of any danger warning sounds are heard, and the females and the young then crowd together, while the old males, like the champions of the ancient Greeks, advance into the foremost of the fight uttering fearful cries, bellowing, and gnashing their teeth. A bold and proud spirit with contempt of death is beyond question a characteristic trait of the baboons, and when Brehm records a case in which an old Arabian male baboon gradually managed to extricate a young one, which had been left behind on a rock surrounded by dogs, from the midst of its assailants and before the very eyes of the hunters, inspiring by its determined bearing both dogs and hunters with such respect for its powers that no attack was ventured on, we may well agree with Darwin in saying that here was a proof of heroism of which only few men were capable."

The characteristically herbivorous order of Ungulates illustrates a number of points in connection with retreat from enemies. It includes, for instance, many examples of extraordinary fleetness, as in the case of horses and their allies, deer, antelopes, and giraffes. It is usual for such forms to live in social communities, the safety of which while feeding is provided for by the posting of sentinels. A well-known instance of the latter habit is afforded by the Alpine Chamois (*Rupicapra tragus*), which feeds during the day in small herds of about a score individuals, the welfare of which is watched over by an old female, who takes up a position giving a wide outlook, and warns her associates of danger by a sharp whistling cry. Retreat is often cleverly effected by such gregarious forms, as, for instance, by the little antelopes known as Duyker-Boks (species of *Cephalophus*), which "duck" down among the bushes among which they feed in a way which has

earned for them their Boer name. They also run in a remarkable zigzagging manner. The Common Koodoo (*Strepsiceros kudu*), a large and handsome antelope, is described as rushing in retreat through thickets of "wait-a-bit", and other thorny plants, in a way that must prove effective in baffling most pursuers, besides which old bulls of this species are credited with rendering themselves inconspicuous by lying down against a suitable bush and raising their heads so that the large twisted horns rest on the back, a position in which they are not likely to attract attention.

Perhaps the most interesting device which helps to save many of the weaker Ungulates from their inveterate enemies, the larger Carnivora, is the habit of "ruminating" or "chewing the cud", which is characteristic of one large group, the Ruminantia. The structural arrangements related to this have been described elsewhere (p. 168), and its protective nature is obvious. A ruminant animal can crop a large quantity of food very rapidly, swallowing it without proper mastication, and then retreating to some comparatively safe place, where the "cud" can be chewed at leisure. In this process the food again returns to the mouth in successive boluses, and is swallowed for a second time after being properly divided and saturated with saliva.

Many of the Mammalia possess Dwellings, to which they retreat when attacked. Rabbits furnish a particularly good example, and everyone who has attempted to shoot these animals is familiar with their habit of popping into their burrows with lightning-like rapidity on the least alarm. A favourite time for feeding is just when it begins to get dark, and it is then that the neutral colour of the fur harmonizes best with the general surroundings so as to render detection a matter of difficulty. Like so many other social forms rabbits appear to make arrangements for the safety of the community by the more experienced members giving warning of approaching danger. This purpose appears to be served, for example, by the curious and emphatic way in which the old bucks stamp on the ground when alarmed. It is somewhat remarkable that an animal like the rabbit, which is protectively coloured, should have a white under-surface to the tail, being thereby made particularly conspicuous when in motion. This has been interpreted with some probability as a case of "signalling coloration", enabling the rapid retreat from danger of an individual to be quickly seen by other rabbits in the neigh-

UNIV. OF
CALIFORNIA

THE CHAMOIS (RUPICAPRA TRAGUS)

DRAWN FROM THE LIFE BY F. SPECHT

UNIV. OF
CALIFORNIA

bourhood. Such a warning is, of course, given unconsciously and is quite on a different footing from the stamping above mentioned, which one must presume is meant by the giver to indicate the approach of danger to his fellows.

Another burrowing rodent which lives in communities is the Prairie-Dog (*Cynomys Ludovicianus*) of the western prairies of North America. It is asserted by several observers that in this case sentinels are regularly set for the common good.

Burrowing animals surprised by enemies when at some distance from their homes commonly attempt, with more or less success, to take refuge in the ground. Of this a notable example is the Small Armadillo (*Dasypus minutus*) of South America, which, when overtaken by a horseman, is said, if the soil is favourable, to be able to burrow a safe distance into the ground before its pursuer has time to dismount, unless he literally falls off his horse.

Arboreal mammals, if surprised on the ground, naturally take to the trees if they have the chance, and they may do this in a very cunning way. If, for instance, an ordinary Squirrel (*Sciurus vulgaris*) (fig. 508), surprised in the act of feeding upon fallen cones or beech-mast, be hotly pursued, it will naturally make for the nearest tree, which it will ascend with great rapidity, always taking the greatest care to direct its flight so that the trunk or branches intervene between itself and the aggressor. It has also been suggested that the squirrel's brush is not only a means of balancing, but also helps escape from carnivorous enemies which, attacking from behind, may at the last moment have to be content with a mouthful of fur. Possibly also, though this is mere conjecture, the delicate and easily-detached tail of the Dormouse (*Muscardinus avellanarius*) may serve as a kind of sop to the foe, on the principle which has before now led to the escape of sledge-travellers from pursuing wolves, which have checked their pace in order to investigate articles of clothing and other objects thrown out for their inspection.

Aquatic mammals in retreat of course take to the water if they get a chance, and some terrestrial forms, such as Deer and Kangaroos, select the water in order to make a last stand against dogs, seeming to realize that attack is thus made more difficult.

Birds in Retreat.—Among the large Running Birds are forms, like the African Ostrich, in which the absence of powers of flight

is largely compensated by the specialization of the legs for the purpose of rapid movement on the ground. For straightforward retreat in open country nothing could be more effective; but another kind of adaptation is required in birds like Rails, which, though belonging to the Flying Birds, are deficient in powers

Fig. 508.—The Common Squirrel (*Sciurus vulgaris*)

of flight, and yet are able to run through thickly-growing vegetation with such rapidity as to commonly elude their enemies. This is rendered possible by the shape of their bodies, which are relatively narrow and flattened from side to side, so as to easily slip between the stems of grasses, rushes, and similar plants. Anyone who has pursued our native Land-Rail or Corn-Crake (*Crex pratensis*) with intent to capture will have noted how extremely difficult it is even to get within sight of a bird of this sort. Certain birds, unfortunately for themselves, have lost the

power of flight without correspondingly increased powers of running, and have paid the penalty of extinction. Such an arrangement, as might be anticipated, was the result of evolution in islands devoid of any predatory ground-animals, and a classic example of it is afforded by the Dodo and its allies, birds related

Fig. 509.—The Dodo (*Didus ineptus*)

to the pigeons. The Dodo itself (*Didus ineptus*) (fig. 509) was a large and clumsy-looking species that at one time abounded in the island of Mauritius, which, like oceanic islands generally, possessed no native mammals, while its indigenous reptiles were only represented by lizards. The ubiquitous sailor, however, and the animals (especially swine) which he introduced, brought about the extinction of this helpless bird in less than a century after its first discovery in 1598. Its memory is now only kept green by a few contemporary drawings and descriptions, certain museum

remains, and the proverb "as extinct as a dodo". As Belloc (in *The Bad Child's Book of Beasts*) pathetically sings:—

"The Dodo used to walk around,
And take the sun and air,
The Sun yet warms his native ground—
The Dodo is not there!
That voice that used to squawk and squeak
Is now for ever dumb—
Yet may you see his bones and beak
All in the Mu-se-um."

A similar fate must overtake any organism suddenly exposed to new and unfavourable conditions, if devoid of sufficient plasticity to rapidly accommodate itself to the altered environment.

Ordinary flying birds naturally betake themselves to flight when attacked, but this is often insufficient to save them from predatory species of their own class. Under such circumstances the flight may be conducted in such a way as to increase their chance of escape. Houssay (in *The Industries of Animals*) gives a good instance of this, drawing the facts from Naumann (*Naturgeschichte der Vögel Deutschlands*): — "Larks, a feeble race of birds, rise higher in the air than any rapacious bird, and this is often a cause of safety. Their greatest enemy is the Hobby (*Hypotriorchis sublutes*). They fear him greatly, so that as soon as one appears singing ceases, and each suddenly closes his wings, falls to the earth, and hides against the soil. But some have mounted so high to pour out their clear song that they cannot hope to reach the earth before being seized. Then, knowing that the bird of prey is to be feared when he occupies a more elevated position from which he can throw himself on them, they endeavour to remain always above him. They mount higher and higher. The enemy seeks to pass them, but they mount still, until at last the Hobby, heavier, and little accustomed to this rarefied air, grows tired and gives up the pursuit."

Climbing Birds, such as Woodpeckers, pursue the same kind of tactics as squirrels (see p. 367), working round a trunk or branch so as to keep it between them and the enemy. The powers of diving possessed by many aquatic birds naturally stand them in good stead when retreating from foes.

Reptiles in Retreat.—The great majority of reptiles are timid and seek refuge in flight on the first alarm. Some Lizards, when

hard pressed, are able to baffle their foes in a somewhat singular manner, comparable to some extent to the supposed way in which squirrels may escape pursuers with no more serious loss than a mouthful of fur from the bushy tail. Here, however, there is no doubt about the facts. A Lizard's tail very readily breaks off, owing to the existence of a weak place in the backbone, specially evolved, we must imagine, to facilitate such an arrangement. While the enemy is negotiating the piece of tail the animal itself commonly manages to make its escape. Such a sacrifice is not so great as might at first sight appear, for a new tail soon grows from the stump. In our native snake-like lizard, the Blindworm (*Anguis fragilis*), which has earned its specific name from the possession of such a brittle tail, a further point was noted by the late J. G. Wood. According to him, the detached tail executes lively movements for some time, a performance which would be likely to divert attention during the escape of its owner. In some of the Australian Geckos the detachable tail is broadened out at the end into a coloured flap, which is supposed to fix the attention of an enemy on a part which can readily be surrendered without fatal result.

The cylindrical smooth body of a Snake or Snake-like Lizard is well suited for slipping through a dense undergrowth of vegetation, and is a great advantage in retreat.

Amphibia in Retreat. — One case only of special interest will be mentioned. Hudson (in *The Naturalist in La Plata*) describes a "Wrestler Frog", possessing extremely muscular fore-limbs, and which, when followed up, makes a feint attack upon its enemy before retreating. Part of his account may well be quoted here:—"The frog is a most timid, inoffensive creature, saving itself, when pursued, by a series of saltatory feats unparalleled amongst vertebrates. Consequently, when I find a frog, I have no hesitation in placing my hands upon it, and the cold sensation it gives one is the worst result I fear. It came to pass, however, that I once encountered a frog that was not like other frogs, for it possessed an instinct and weapons of defence which greatly astonished me. I was out snipe-shooting one day when, peering into an old disused burrow, I perceived a burly-looking frog sitting within it. It was larger and stouter-looking than our common Rana, though like it in colour, and I at once dropped on to my knees and set about its capture.

Though it watched me attentively, the frog remained perfectly motionless, and this greatly surprised me. When I was sufficiently near to make a grab, it sprang straight at my hand, and, catching two of my fingers round with its fore-legs, administered a hug so sudden and violent as to cause an acute sensation of pain; then, at the very instant I experienced this feeling, it released its hold and bounded out and away." The specimen, however, was captured, but later on managed to escape from the box in which it was imprisoned, and Mr. Hudson failed to secure another individual of the same sort. "That this singular frog has it in its power to seriously injure an opponent is, of course, out of the question; but its unexpected attack must be of great advantage. The effect of the sudden opening of an umbrella in the face of an angry bull gives, I think, only a faint idea of the astonishment and confusion it must cause an adversary by its leap, quick as lightning, and the violent hug it administers; and in the confusion it finds time to escape. I cannot for a moment believe that an instinct so admirable, correlated as it is with the structure of the fore-legs, can be merely an individual variation; and I confidently expect that all I have said about my lost frog will some day be confirmed by others. *Rana luctator* [*i.e.* the Wrestling Frog] would be a good name for this species."

Retreat among various Invertebrates.—Among Mollusca we find a very interesting and well-known device for securing a safe retirement when attacked by foes in Cuttle-Fishes and the like. These animals possess an ink-bag (the secretion of which was the original source of the pigment "sepia") from which a dark fluid can be ejected at will. The result is the production of a cloudiness in the water for a considerable distance, under cover of which the Cuttle-Fish commonly manages to beat a successful retreat. Hickson (in *A Naturalist in Celebes*) thus describes this proceeding:—". . . I often saw advancing slowly over the sea-gardens, in parties of from four to six, a group of cuttle-fish, swimming with an even backward movement, the fringes of their mantles and of their arms trembling, and their colour gradually changing to what seemed to me to be an almost infinite variety of hues as they passed over the various beds of the sea-bottom. Then suddenly there would be a commotion in what was previously a calm and placid scene, the striped and speckled reef-fishes would be seen darting away in all directions, and of the cuttle-fishes all that remained were four or

five clouds of ink in the clear water. The appearance in the neighbourhood of a small shark or other kind of voracious fish was the cause of this sudden agitation, and the cuttle-fishes, after squirting out a cloud of ink to 'throw dust in the eyes' of their enemy, had, by violent contractions of their mantle, made off."

Certain kinds of Land-Snails have been described which often succeed in escaping their enemies by the same kind of device as that described for Lizards. This is the case, for instance, with a number of small forms of the kind (species of *Helicarion*) inhabiting the Philippines. These crawl rapidly upon trees by means of a long narrow foot, of which the hinder part is very conspicuous and bears a projecting horn-like process. If such a snail, when crawling, is seized from behind, this tail-like part of the foot is jerked convulsively up and down till it becomes detached, when its owner promptly drops to the ground or conceals itself among adjacent leaves.

A common British Land-Snail (*Vitrina pellucida*) uses the tail-like hinder part of the foot as a springing organ, by which it can throw itself to the ground if alarmed when crawling along in an exposed situation. Some Sea-Snails possess jumping powers of no mean order (*e.g.* species of *Strombus* and its allies) which must often be of use in helping them to retreat from enemies. Even some of the bivalve molluscs are endowed with similar powers, as is notably the case in the Common Cockle (*Cardium edule*), and here again rapid and sudden retreat from foes is no doubt one of the ends served.

Some of the Social Insects, especially Ants, wage warfare very scientifically, and their retreats are carried out in good order, regulated by tactical principles. There are also insects with special powers of fighting in retreat. An example is the Bombardier Beetle (*Brachinus crepitans*), in which the hinder part of the intestine is provided with glands which secrete a volatile fluid possessed of noxious properties. When one of these creatures is pursued by a large carnivorous beetle it ejects small portions of the fluid, which immediately vaporizes, producing what looks like a tiny puff of smoke. At the same time a sharp report is heard, resulting from the sudden ejection, and the arrangement is one calculated to discomfit an enemy.

Spiders combine death-feigning with retreat, falling from their webs when attacked as if the victims of sudden dissolution. They

do not forget, in so falling, to spin a thread of silk by which to climb back to their home in case the manœuvre is successful. Some Caterpillars also, if alarmed when feeding on a branch, will suddenly let themselves drop and remain suspended by a thread of silk, and so also do some Slugs (fig. 510), though in their case the thread is of different character.

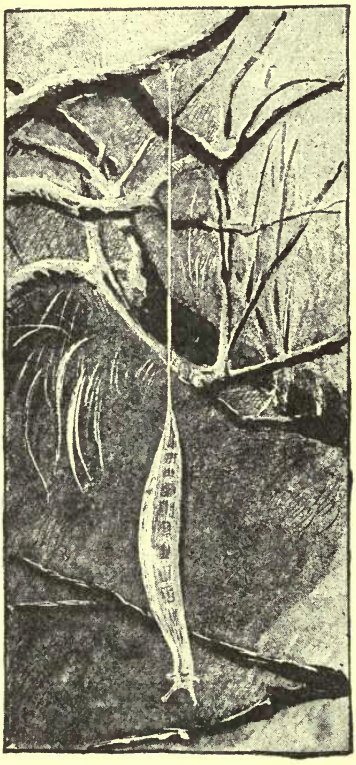


Fig. 510.—Slug suspended by a thread of hardened slime

Many of the Crustacea are able to retreat in an effective manner, and this is obviously possible with powerful swimmers such as Lobsters and Prawns, which, when pursued, make at full speed for some sheltering hole or crevice. The Common Shrimp (*Crangon vulgaris*), and similar forms, swim off quickly when alarmed, clouding the water as they do so by scuffling up the sand on which they live. Before the water clears itself again they will be found to have neatly buried themselves in the sand, though even then they are not safe from fishes which use the sense of smell to guide them in the chase, as many do. Some of the little crabs commonly seen on our shores are pretty nimble, but their pace is contemptible compared with that of the Swift Sand-Crabs (*Ocypodidæ*) of African and American shores, which scuttle away at a great rate when frightened, and are also able to bury themselves in the sand with extreme rapidity. Crustacea are further distinguished by the readiness with which they part with their limbs, and many of them have doubtless survived frequent hairbreadth escapes by pursuing this policy, reminding one of the case of Lizards already noted (see p. 371). Members lost in this or any other way quickly sprout again.

The power of regeneration alluded to above is present to a much greater extent in segmented worms or Annelids. A marine, freshwater, or terrestrial worm of this kind, if overtaken by an enemy, is nevertheless not at the end of its resources, for even

a large piece of its body, if bitten off, can be renewed. And cases must frequently occur where the front end of such a creature manages to make its escape while the pursuer is devouring the piece which he has captured. It has been plausibly suggested that segmentation of the body, in its first origin, was evolved as a defensive measure. A lower form constructed in this way consists of a series of rings or segments, sometimes extremely numerous, each of which contains a portion of most of the organs, digestive, excretory, nervous, &c., so that even the loss of a considerable number of segments leaves the animal sufficiently well provided in these respects to carry on its existence till the wound is healed and the parts destroyed have grown once more. In the higher segmented forms (Arthropods, Vertebrates) the body has become so specialized that this mode of defence has been mostly or entirely given up, though even in so highly developed an animal as a Lizard the part which can be relinquished and renewed, *i.e.* the tail, is made up of the posterior segments of the body.

ANIMAL RESPIRATION—THE BREATH OF LIFE

CHAPTER XXXI

ANIMAL RESPIRATION—GENERAL PRINCIPLES—BREATHERS IN WATER AND BREATHERS IN AIR

GENERAL PRINCIPLES

The essential nature and purpose of breathing or respiration have been explained elsewhere (vol. i, p. 45), but it may be desirable in this section to call attention to a few points of general interest. The living substance of which the bodies of animals are more or less composed is of exceedingly unstable nature, and is constantly breaking down into simpler substances (see p. 3), this process of waste being continually counterbalanced by the taking in of food, which is built up into fresh body-substance. An animal may, in fact, be regarded as a self-repairing machine. In the last section we have considered very fully the food and feeding of animals, and have seen that the necessity for repair of waste, and for growth to a certain size, exert a very far-reaching influence upon bodily characteristics and habits.

We are now more particularly concerned with the other part of the cycle of chemical changes which incessantly goes on within the living body, *i.e.* with the down-breaking processes or processes of waste. It is these which yield the obvious or actual energy necessary for the performance of all the vital actions, including the heat which is so characteristic of warm-blooded active creatures like mammals and birds. Such down-grade chemical processes, as they may perhaps be called, are quite comparable to those which go on in a burning candle or lamp, *i.e.* they are a kind of combustion. And both in the case of the animal body, and in the case of

lamps or candles, combustion cannot go on without continual access of fresh supplies of air, for the sake of the oxygen gas which is contained in it. The burning of a candle is due to a process of what is known chemically as *oxidation*, the oxygen of the air uniting with the wax of the candle, which as a result is transformed into simpler chemical substances, chiefly water (H_2O) and carbonic acid gas (CO_2). If a cold dry tumbler is held over a burning candle a sort of mist condenses upon the inner side of the glass, and this is some of the water in question. And again, if a candle-end is burnt for a time in a tumbler into which a small quantity of clear lime-water has been poured, a little gentle shaking will be followed by a milky appearance in the lime-water, due to the formation of carbonic acid gas as one result of the burning. This gas unites with the lime-water so as to produce minute particles of carbonate of lime, which give rise to the milkiness. The slow combustion constantly going on in the animal body similarly causes its complex living substance to break down into a number of much simpler compounds, among which are to be found both water and carbonic acid gas. Such compounds, being of no use, are called *waste products*, and have to be passed out of the body. And one of the reasons why an animal is obliged to breathe is that it may get rid of carbonic acid gas, together with a large amount of water. You can easily satisfy yourself that this is true as regards a human being by directing some of your outgoing breath against a cold looking-glass, when a film of moisture (*i.e.* water) will be seen. And the presence of carbonic acid gas in such breath can be proved by breathing into some clear lime-water, which will at once become milky.

Breathing or respiration has a double purpose, for it not only gets rid of waste products, but is also the means by which the oxygen necessary for promoting the breaking-down processes of the body is taken into the system. This oxygen is absorbed into the blood, or, in some of the simpler animals, what corresponds to it, and is taken to all parts of the body, in order that they may "waste" and give up their share of the energy necessary for working the different organs.

Some of the smallest and simplest animals breathe by the general surface of the body, but in higher forms, especially those which live on land, this is not possible, and all sorts of complicated breathing arrangements exist. We get, in fact, special

breathing or *respiratory organs*, the special duty of which is to take in oxygen and get rid of carbonic acid gas and water. Nor must we underestimate the importance of this kind of work, since it may be stated broadly that the activity and intelligence of an animal are proportionate to the efficiency of its breathing organs. For rapid movement means quick wasting of the muscles, and this is not possible unless abundant oxygen is supplied and waste products speedily removed. And great intelligence is associated with rapid oxidation of brain-substance, and similar quick removal of waste substance. It may also be said that, as a general rule, efficient breathing organs are associated with efficient circulatory organs. The most active and most intelligent groups of animals now existing are undoubtedly mammals, birds, and insects, all of which are particularly well off in the matter of breathing arrangements.

One very important principle in regard to such organs must be carefully borne in mind. Great efficiency as regards breathing organs means the existence of a large surface in close proximity to the blood, so that on the one hand oxygen may pass in, and on the other carbonic acid gas and water pass out. And we shall find that a large surface may, by various devices, be packed away in a comparatively small space, and further, that it is often associated with complicated arrangements by which constant and rapid renewal of air is provided for.

BREATHERS IN WATER AND BREATHERS IN AIR

All animals, without exception, are breathers or intakers of air, or rather of the oxygen gas which it contains, and it is incorrect to speak, as is sometimes done, of "air-breathers" as contrasted with "water-breathers". Some animals, such as whales, though living in water, have from time to time to come to the surface to obtain air for breathing, but a host of aquatic creatures, such as most fishes, crustaceans, marine molluscs, &c., do not find it necessary to do this. The oxygen which they need is not, however, obtained from the water (H_2O) itself, though this consists of oxygen united or combined with hydrogen. But such animals do not possess the power of decomposing water for the sake of the oxygen which enters into its composition. If they did, free hydrogen gas would

constantly be given off from the sea, which we know is not the case. The requisite oxygen is, in fact, *dissolved* in the water, which has absorbed it from the atmosphere. Anyone who has tried to keep animals in an aquarium knows that a shallow vessel is better for the purpose than a very deep one, and this is because there is a relatively large surface by which oxygen can be absorbed. In a very large and deep aquarium either the water must be constantly renewed, or air must be frequently pumped in.

Relation between Plants and the Breathing of Animals.—The statement made in the last sentence requires a certain amount of qualification, for not only do animals depend in the long run upon plants, as regards food, but there is an intimate connection between them in the matter of breathing. It ought to be clearly understood that plants breathe exactly in the same way as animals, so far as essentials are concerned, taking in oxygen gas and giving out carbonic acid gas. Yet, as regards ordinary green plants, the statement is often made that "animals breathe in oxygen and breathe out carbonic acid gas, while plants breathe in carbonic acid gas and breathe out oxygen". This is absolutely incorrect, and why it is so will become apparent if we consider for a moment how, and upon what, green plants feed. Such plants act, so to speak, as intermediaries between the mineral and animal kingdoms, for they convert very simple substances into the materials of which their own bodies are composed, and thus prepare food for animals, as these depend upon a diet of very complex chemical nature (see p. 270). The food of a green plant consists, in fact, of water with mineral substances dissolved in it, and also of carbonic acid gas, this too being dissolved in water in the case of aquatic plants. It is the last kind of food with which we are here concerned. The green colouring matter (chlorophyll) which is characteristic of ordinary plants enables the living substance (protoplasm) with which it is associated to use sunlight in such a way as to bring about chemical action between water and carbonic acid gas. The result of this is twofold, for in the first place a substance is formed which is a step upward in complexity, and in the second place oxygen gas is liberated as a sort of by-product. It is this oxygen gas which is given out by the plant and erroneously supposed to be a result of breathing, whereas it really has to do with the feeding. It is so large in amount as to greatly exceed, during the daytime, the carbonic acid gas which is breathed out by

the plant. We may therefore say that animals, by constantly breathing out carbonic acid gas, keep up the supply of a substance green plants require as a part of their food. Green plants, on the other hand, in the course of their feeding, constantly give out large quantities of oxygen gas, and keep up the supply of that element necessary for breathing purposes. And even if animals could dispense with green plants as food, the absence of such plants would probably soon result in such a diminution of the oxygen in the air and such an increase in its carbonic acid gas, that ordinary animal life would become impossible. There is thus a constant, though, of course, quite unconscious, exchange of good offices between animals and green plants, and the composition of the air is kept uniform for indefinitely long periods of time. It is, however, quite possible, as some have maintained, that in very remote geological periods the air contained a much larger percentage of carbonic acid gas than it does now, and this was possibly one of the causes that led to the luxuriant growth of plants during the geological period (Carboniferous) from the deposits of which most of our coal is obtained.

It is now clear why the remarks already made (see p. 379) about the difficulty which aquatic animals have in breathing, when kept in a deep aquarium, need qualification. For if there is an abundant plant-growth in such an aquarium, a large amount of oxygen is given off which can be breathed by the animals present. When bright sunlight is allowed to fall upon the plants in such an aquarium, small bubbles of gas may often be seen to collect on them, and this, when tested, proves to be oxygen.

In the succeeding chapters of this section it will be convenient first of all to consider the typical breathers in water, since they represent what must have been the original state of things. Typical breathers in air will next be discussed, and afterwards forms which are in process of transition from breathing in water to breathing in air, while mention will also have to be made of air-breathing forms which have reverted to breathing in water for part, at least, of their existence.

CHAPTER XXXII

ANIMAL RESPIRATION—VERTEBRATES THAT BREATHE IN WATER

One of the essential characters of Vertebrate or Backboned animals is the possession, during part or all of life, of slits in the side of the throat (visceral clefts) by which that part of the digestive tube which immediately succeeds the mouth-cavity (*i.e.* pharynx) communicates with the exterior (fig. 511). These slits primarily have to do with breathing, and for that reason may be called *gill-clefts*, since in many cases *gills*, which are organs specially concerned with aquatic breathing, are found as outgrowths of their sides. By studying the development of a fish it is possible to follow the stages in the formation of gill-clefts. The sides of the pharynx grow out into a series of pouches which first of all come into contact with the skin and then fuse with it. Later on, by the absorption of tissue, the actual openings or clefts come into existence.

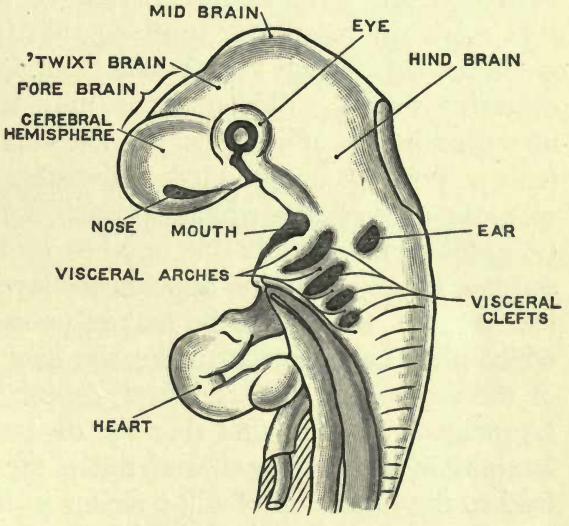


Fig. 511.—Front part of Chick Embryo. Enlarged

When, however, we enquire *how* gill-clefts came to be developed in the remote and so far unknown ancestors of vertebrates, it is impossible to do more than speculate in a general sort of way upon the matter. We know, as a matter of fact, that almost any

part of an aquatic animal to which water has access may help in breathing if its covering or lining is sufficiently thin for the oxygen dissolved in the water to diffuse in, and the carbonic acid of the blood to diffuse out. The lining of the digestive tube is commonly sufficiently delicate to satisfy this condition, and since an aquatic animal takes in more or less water with its solid food, it therefore follows that in many marine worms, &c., breathing is to some extent performed by the tube in question. It is also obvious that the beginning of the digestive canal is most favourably situated for the purpose, and it is therefore not surprising to find that aquatic breathing has in many instances been localized in the pharynx. A breathing organ, to be efficient, must possess a sufficiently large surface for exchange of gases between the blood and the surrounding medium; hence any folds or pouches in the sides of the pharynx would add to its utility in this particular direction. And here the very pertinent question naturally presents itself—"Is there any reason for thinking that the lowly and long-extinct creatures from which Vertebrates have sprung possessed a pouched digestive tube?" This question may be, with some probability, answered in the affirmative, for Vertebrates are *segmented* animals (see p. 375), *i.e.* are divided from before backwards into a series of parts or *segments* which, in such a low type as the Lancelet (Amphioxus), resemble one another pretty closely. The original purpose of segmentation appears to have been lost in Vertebrates (see p. 375), and it is to be looked upon as an inherited character which they have had to make the best of. If we examine some of the segmented Invertebrates, especially the segmented worms (Annelids), we shall find that the digestive tube often bulges out laterally in each segment, and this is the very feature which might lead to the formation of gill-pouches in the region of the pharynx. How and why these pouches first came to open externally is a very difficult problem, but we know that such structures may communicate with the exterior, for in some of the Sea-Slugs (Nudibranchs, see p. 357) there are tubular branches of the digestive tube which open upon horn-like projections (*cerata*), probably for the purpose of getting rid of certain waste products. A similar reason may explain the origin of gill-slits in the remote past. Be that as it may, such openings once established would greatly increase the efficiency of the pharynx as a breathing organ, for they would afford a means of exit for water taken in at the mouth,

and such water would then be regularly taken in for respiratory purposes instead of passing in casually with the food. Though, judging from analogy with some crustacea and other animals where the last part of the intestine is pressed into the service of breathing, there may have been a stage before gill-slits were evolved, in which breathing-water was taken into the pharynx at regular intervals and as regularly ejected from the mouth after doing its work. Leaving the realm of speculation, we come to the breathing arrangements found among the chief groups of Fishes, and among the simply-organized forms known as Protochordates.

FISHES AS BREATHERS IN WATER

LAMPREYS AND HAGS (CYCLOSTOMES)

One of the most interesting forms as regards breathing organs in this very ancient and primitive group is the Californian Hag-Fish (*Bdellostoma*) of the Pacific coast. This is an elongated eel-shaped creature with suctorial mouth, devoid of anything

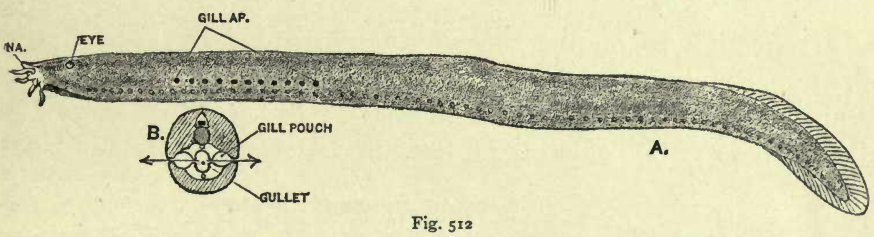


Fig. 512

A, Californian Hag-Fish (*Bdellostoma*), reduced, showing external apertures of the gill-pouches. NA, Unpaired nostril. B, Diagrammatic cross-section of same, showing two gill-pouches connected with the gullet and the exterior. Course of the breathing-water indicated by arrows.

comparable to a lower jaw. On each side of the body are to be seen, a little distance behind the head, some seven to fifteen small round holes, one behind the other (fig. 512). These are the external openings of a corresponding number of gill-pouches. Dissection shows that the pouches communicate internally with the digestive tube by similar apertures, and that the lining of each pouch is raised into a large number of thin folds, arranged almost like the leaves of a book, and presenting a very large surface for purification of blood. The heart contains nothing but impure blood, loaded with carbonic acid gas and deficient in oxygen. This it pumps to the gill-pouches, where dissolved oxygen is taken up from the surrounding water, which receives

in exchange, so to speak, the waste carbonic acid gas. The purified blood is then distributed to all parts of the body (fig. 513).

In cases where organs of any sort are repeated to form a series, it frequently happens that increased efficiency is gained

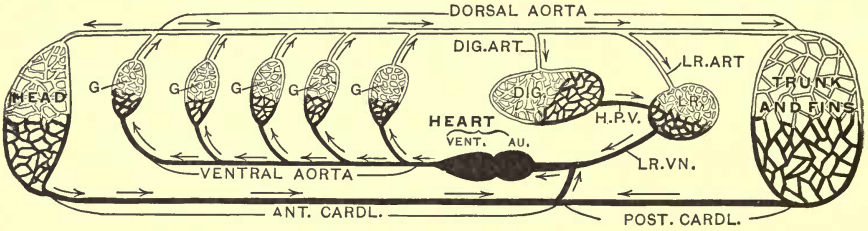


Fig. 513.—Diagram of Circulatory System in a Fish

The direction of blood-flow is indicated by arrows; vessels containing pure blood left unshaded, those containing impure blood are darkly shaded. The capillaries of head, gills (GGGGG), digestive tube (DIG.), liver (LR.), trunk, and fins are represented as net-works.

The heart essentially consists of an auricle (AU.) and ventricle (VENT.), and pumps impure blood to the gills, where it is purified, afterwards passing to the dorsal aorta for general distribution. The impure blood is returned to the heart by paired anterior cardinal (ANT. CARDL.) and posterior cardinal (POST. CARDL.) veins. The liver receives pure blood by a liver-artery (LR. ART.) and also impure blood (from stomach, intestines, pancreas, and spleen) by an hepatic portal vein (H.P.V.). Its impure blood is returned to the heart by a liver-vein (LR.VN.). The complex circulatory arrangements of the liver are known as the 'hepatic portal system". (DIG. ART.), Artery carrying pure blood to stomach, &c. The gills and gill-vessels of one side only are indicated.

by a reduction in number, usually accompanied by specialization of the surviving members of the series. Good examples are furnished by the reduction in number of the teeth of some Carnivores (see p. 7), of walking-legs in Insects as compared with

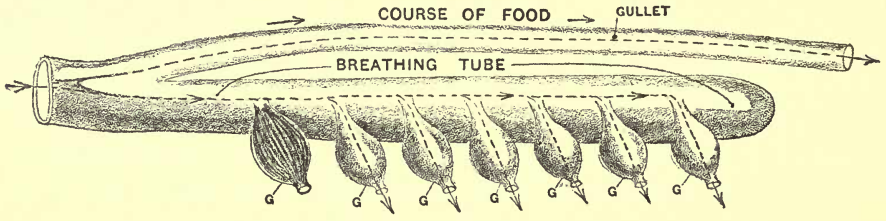


Fig. 514.—Diagram showing the gill-pouches (G) of one side in a Lamprey (*Petromyzon*)

Scorpions or Centipedes, and of digits in the Horse, which has one large efficient toe as contrasted with the five of a Man. And when we examine the breathing organs of a Lamprey (*Petromyzon*) we find only *seven* pairs of gill-pouches, a great reduction as compared with the Californian Hag-Fish. Nor do these pouches open directly out of the digestive tube, but they communicate internally with a breathing tube which underlies and is connected in front with this (fig. 514).

A very interesting and curious specialization is found in the Common Hag-Fish (*Myxine*), a form which abounds on the east coast of Scotland. For here there are only *two* external openings, situated rather far back on the under side of the body. On dissection we find that there are six pairs of gill-pouches, opening directly out of the digestive tube, but those of each side communicate externally with a canal which opens to the exterior by one of the two openings already noted (fig. 515). This is probably connected with the habit this fish has of attacking cod, &c., in a moribund condition, and eating its way into their bodies. This practice would interfere with breathing if the gill openings were arranged as in a Lamprey. A further interesting point about the Hag is the existence of a useless *seventh* gill-passage behind the pouches of the left side, and this vestige clearly indicates that the fish is descended from forms possessing more numerous gill-pouches than it does itself. Such a conclusion is borne out by the facts already mentioned regarding the number of gill-pouches in other members of the group.

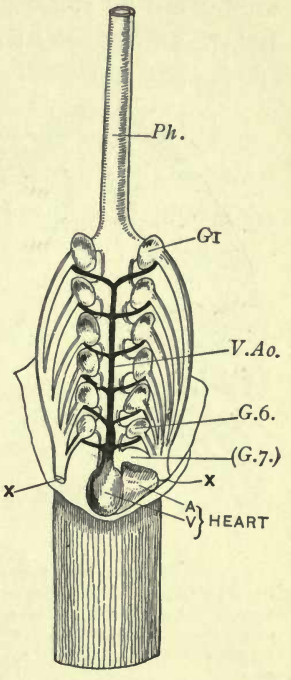


Fig. 515. — Circulatory Breathing Organs of Hag (*Myxine glutinosa*), dissected from below

A, auricle; V, ventricle; *V.Ao.* ventral aorta taking impure blood to the gill-pouches; *Ph.* pharynx; *G1* and *G6*, first and last gill-pouches of left side; *G7*, vestige of seventh gill-pouch on left side; **X X**, the two external gill apertures

SHARKS AND RAYS (ELASMOBRANCHS)

A description has already been given (vol. i, p. 257) of the structure of the Spotted Dog-Fish (*Scyllium canicula*), which is in effect a small shark. In this creature, as in most of its kind, five gill-clefts are readily seen on each side of the body a little way behind the head, and these are the external openings of a corresponding number of gill-pouches which communicate internally with the pharynx (fig. 516). Projecting into each pouch are a large number of folds, collectively presenting a large surface for purification of the blood. The breathing-pouches of a Lamprey are supported and prevented from collapsing by a basket-work of

horny fibres, and there is a similar arrangement in the Dog-Fish, for the thick partitions (gill-arches) between the gill-pouches are supported by jointed hoops of gristle, which unite with one another below, and answer the same purpose. Special muscles are attached to this framework, which act so as to adjust and promote the outward flow of water through the gill-clefts.

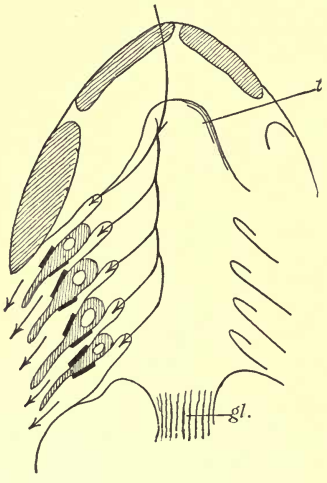


Fig. 516.—Horizontal section through the Breathing Organs of a Dog-Fish or Shark, showing the gill-pouches. The gills are deeply shaded and the course of the breathing water indicated by arrows. *t*, Tongue; *gl*, gullet.

There is good reason for thinking that the number of gill-clefts in a Dog-Fish or Shark is a reduction upon an earlier state of things, and it is interesting to note that two existing kinds of Shark (*Hexanchus* and *Heptanchus*) possess respectively six and seven pairs of such clefts; besides which, it has recently been discovered that in one species of Dog-Fish there are remains (vestiges) of a sixth pair of clefts behind the last existing pair. It is also to be observed that reduction has taken place not only from behind, but also from in front, for just behind the eye of a Dog-Fish or Shark there is a small round hole, the spiracle, with which the pharynx communicates by means of a narrow passage (spiracular cleft). That this is an old gill-cleft which is being utilized for other purposes is conclusively proved by the fact that it contains some small folds which are undoubtedly the last traces of a disappearing gill. These folds are known as the *false-gill* (*pseudobranch*). The new use to which this old gill-cleft is being put is the transmission of sound to the essential organs of hearing, which are enclosed in a gristly ear-capsule adjoining the front wall of the cleft. In a Skate (*Raia batis*) there is a thin place in the wall of this capsule to facilitate the conduction of sound. This is a particularly striking case of "change of function", and it acquires much greater interest when we come to investigate the structure of the organs of hearing in such forms as mammals, birds, reptiles, and amphibians. For outside the ear-capsule of these animals there is a cavity or "drum", covered externally by a tense membrane, from which sound-waves are carried across the drum by one or more little bones (see vol. i, p. 56) to the

essential organs of hearing contained in the capsule. This drum is the equivalent of the spiracular cleft of a Dog-Fish, and it is therefore clear that the backboned animals which live on land have pressed an old gill-cleft into the service of their hearing organs, which is in itself sufficient proof that these animals have descended from aquatic gill-possessing ancestors.

In some fishes of the Shark kind the internal openings of the gill-pouches are guarded by slender projections ("gill-rakers"), the use of which is to prevent foreign bodies or bits of food from passing into the pouches and choking them up.

SEA-CATS (HOLOCEPHALI)

The members of this small group are closely related to the Sharks, but are in advance of them so far as breathing organs are concerned. The best-known of them is the Sea-Cat, or King of the Herrings (*Chimæra monstrosa*). There is here no spiracle,

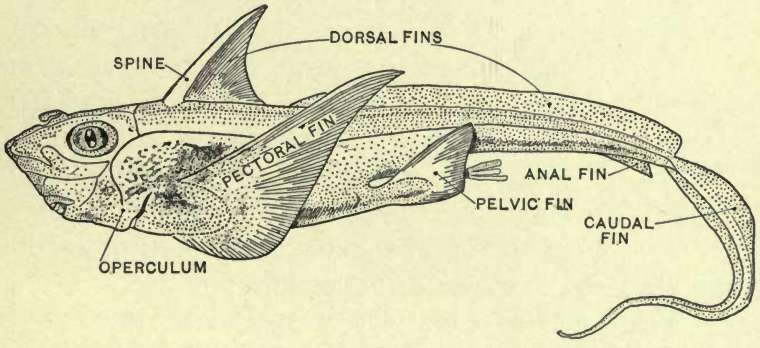


Fig. 517.—The Sea-Cat (*Chimæra monstrosa*), male

and the gill-clefts, which are close together, are reduced to four in number. Externally they are protected by a flap or gill-cover (*operculum*), supported by gristle (fig. 517). We shall see in the sequel that various arrangements have been evolved in different sorts of aquatic animals for the protection of the gills, for these structures are necessarily of delicate texture (or exchange of gases could not take place through their walls), and are not only liable to be injured by grains of sand and the like, but are also much favoured by parasites, which find in them a sheltered home provided with a very rich supply of blood.

ORDINARY BONY FISHES (TELEOSTEI)

In such fishes as Salmon, Perch, or Cod there is further specialization in the breathing organs, resulting, it would seem, in increased efficiency, which is no doubt one reason why this youngest group of fishes is predominant at the present day.

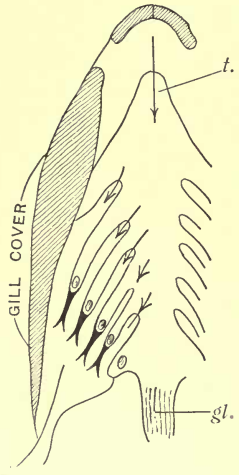


Fig. 518.—Horizontal section through the breathing-organs of a Teleost. The freely-projecting gills are darkly shaded, and the course of the breathing-water indicated by arrows. *t.* Tongue; *gl.* gullet.

There is no spiracle, and the gill-slits are usually *five* in number (though they may be fewer), and close together. The most remarkable peculiarity, however, concerns the gill-folds, and it is one to which Chimæra and Sturgeons lead up. Each such fold, instead of being attached along its whole length to the side of a deep gill-pouch, is here present as a thread or filament, fixed by one end to a comparatively narrow gill-bar (fig. 518). The gill-bars are, as it were, the greatly-reduced representatives of the partitions which separate the gill-pouches in a Dog-Fish or Shark. An ordinary bony fish possesses a large gill-cover or operculum, supported by several flat bones, and if we lift this up the gill-filaments are to be seen aggregated into a number of red comb-like gills, the filaments corresponding to the teeth of the combs. The evolution of the protective gill-cover has rendered such an arrangement possible.

Many Teleosts also exemplify a special device by which a regular flow of water over the gills is promoted. There are valvular flaps (inner lips) just within the mouth, and similar flaps close to the slits behind the gill-covers. When the fish opens its mouth and dilates its pharynx the latter valves close, so that water enters from the front *only*, none passing in under the gill-covers and through the gill-clefts. As the mouth shuts, its valves come together, so that *all* the water that has been taken in is forced out through the gill-clefts, and is entirely prevented from being ejected again in front without having done any breathing work.

PROTOCHORDATES

In describing the breathing organs of fishes use has several times been made of the word "gill", and it is time to enquire

what is meant by this expression. A *gill* is an outgrowth from the body, or it may be a collection of outgrowths, the use of which is to assist breathing in water. It is, in fact, a means of increasing the surface through which the dissolved oxygen in the surrounding water can pass into the blood, while on the other hand waste carbonic acid from the blood diffuses out into the water. In an ordinary bony fish each comb-like aggregate of filaments may be termed a gill in this sense.

In the lowest animals (Protochordates) which have any claim to be considered vertebrates there are no gills in the sense just explained, but the perforated walls of the pharynx offer a sufficiently large surface to serve the purpose of breathing. In the

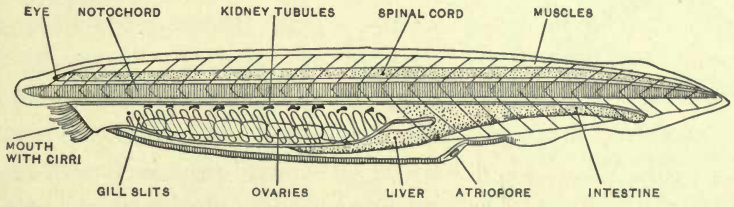


Fig. 519.—Lancelet (*Amphioxus lanceolatus*)

Side view, with internal organs seen by transparency. Semidiagrammatic

Lancelet (*Amphioxus*), for example, the pharynx is exceedingly large, and perforated by a great number of oblique clefts (fig. 519), and, as each of these is again divided by cross-bars, the result is the establishment of a complex basket-work, possessing a very large surface for exchange of gases between the blood and the surrounding water. By means of horny supporting rods the pharynx is stiffened, and the numerous small openings kept from collapsing. Although the Lancelet is low down in the vertebrate branch, it must not be imagined that this complicated arrangement gives any idea of the breathing organs possessed by the first vertebrates evolved, for the richly-ciliated pharynx is a current-producing organ which is essential to feeding (see p. 244), and it has been elaborated in connection with this important function.

The Ascidians or Tunicates possess a pharynx with side-walls converted into a basket-work (see vol. i, p. 297), not unlike that found in the Lancelet, and, as in that animal, its duty is to cause water to stream in at the mouth, bringing with it food and the oxygen necessary for breathing. Both in the Lancelet

and in Ascidians the minute organisms and organic particles which constitute the food would be liable to pass through the lateral perforations of the pharynx and so wasted, if there were not some special arrangement to prevent it. But in each of these cases there is present a groove along the upper side, and a similar groove along the lower side, along which food is conducted to the gullet, entangled in a sticky fluid which prevents their escape.

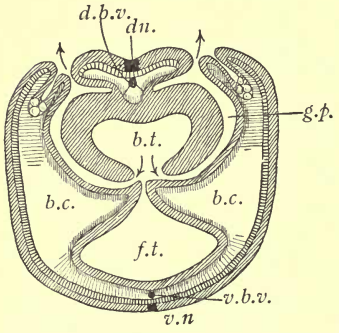


Fig. 520. — Section through an Acorn-headed Worm (*Balanoglossus*) in the region of the pharynx. This is incompletely divided into feeding-tube (*f.t.*) below and breathing-tube (*b.t.*) above. The latter communicates by means of gill-pouches (*g.p.*) with the exterior. The course of the breathing-water indicated by arrows. *b.c.* Body-cavity; *d.b.v.* and *v.b.v.* dorsal and ventral blood-vessels; *d.n.* and *v.n.* dorsal and ventral nerves.

In the Acorn-headed Worm (*Balanoglossus*) (see vol. i, p. 300) the pharynx is divided by projecting folds into a lower food-conducting section and an upper breathing portion (fig. 520). The latter possesses a large number of pairs of gill-pouches, which open to the exterior by rounded pores on the upper side of the body. The walls of these pouches are supported by horny rods closely similar to those which stiffen the side-walls of the Lancelet's pharynx.

In all these Protochordates—and the remark is true for vertebrate animals generally—the pharynx, originally concerned with the digestive function only, has acquired a new use, having been pressed into the service of breathing. Various devices have been evolved to prevent these two distinct duties from interfering with each other, and we have just seen how this is accomplished in the Lancelet, &c. The use of gill-rakers in Fishes has also been explained (see p. 387), and we shall have occasion to note in the sequel the way in which air-breathing vertebrates attempt, with more or less success, to keep the feeding tract distinct from the breathing tract.

CHAPTER XXXIII

ANIMAL RESPIRATION—NEMERTINES—MOLLUSCS WHICH BREATHE IN WATER

NEMERTINES

Some authorities are of the opinion that these curious unsegmented marine creatures, which look like long cylindrical worms (see vol. i, p. 305), resemble in certain respects the remote stock which has given origin to backboned animals. One characteristic feature of such animals is, as we have seen, the possession of a perforated pharynx which has taken on the function of breathing. Nemertines in all probability breathe to a large extent by means of their soft skin, but it is also likely that the pharynx takes part in the same work, although it is not perforated by gill-clefts. And it is certainly a suggestive fact that the straight digestive tube of these creatures bulges out on each side into a series of pouches, resembling in character the structures which probably gave rise to gill-pouches by acquiring external apertures (see p. 381).

MOLLUSCS WHICH BREATHE IN WATER

The vast majority of Molluscs of all kinds live in water, and breathe the oxygen which is dissolved in it. They are predominatingly marine, but some forms live in estuaries, while others have migrated into fresh water, and adapted themselves to the special conditions there existing.

MAIL-SHELLS, &c. (Protomollusca)

The breathing organs are in a comparatively simple condition in the primitive forms known as Mail-Shells (*Chiton*, &c.). Here there is a flattened oval body, protected above by a row of eight

shelly plates, and exhibiting below a large flat muscular foot, by means of which creeping is effected. Overhanging the foot, and running right round the animal, is a flap-like mantle-skirt, the groove under which is known as the *mantle-cavity*. This shelters on each side a varying number of gills (fig. 521), each of which consists of a stalk, on either side of which are arranged a large number of small flat plates. These collectively present a very large surface to the surrounding water, and as the gills are of delicate texture it is easy for the abundant blood which they contain to get rid of its waste carbonic acid gas in exchange for oxygen.

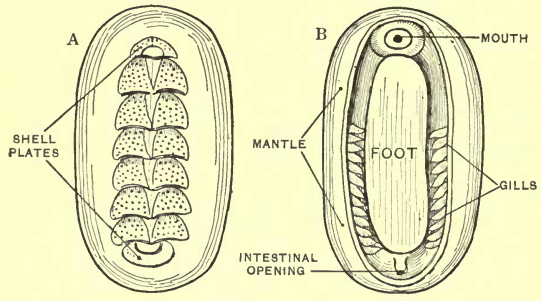


Fig. 521.—Mail-Shell (*Chiton*) seen from above (A) and below (B). Note in B the numerous gills on each side

HEAD-FOOTED MOLLUSCS (CEPHALOPODA)

A Cuttle-Fish (*Sepia*, &c.) or Squid (*Loligo*, &c.) is far more specialized than a Mail-Shell as regards breathing organs. On the hinder side of its long body we can easily find a large gill-cavity, opening below by a large slit, and probably equivalent to the posterior part of the mantle-cavity in the Mail-Shell, greatly enlarged and deepened. Two very large plume-like gills are contained in the cavity (fig. 522), and these probably represent one of the last few pairs of a Mail-

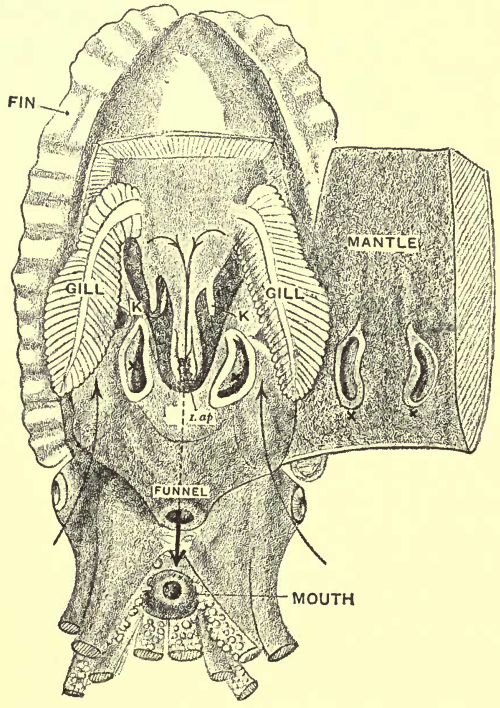
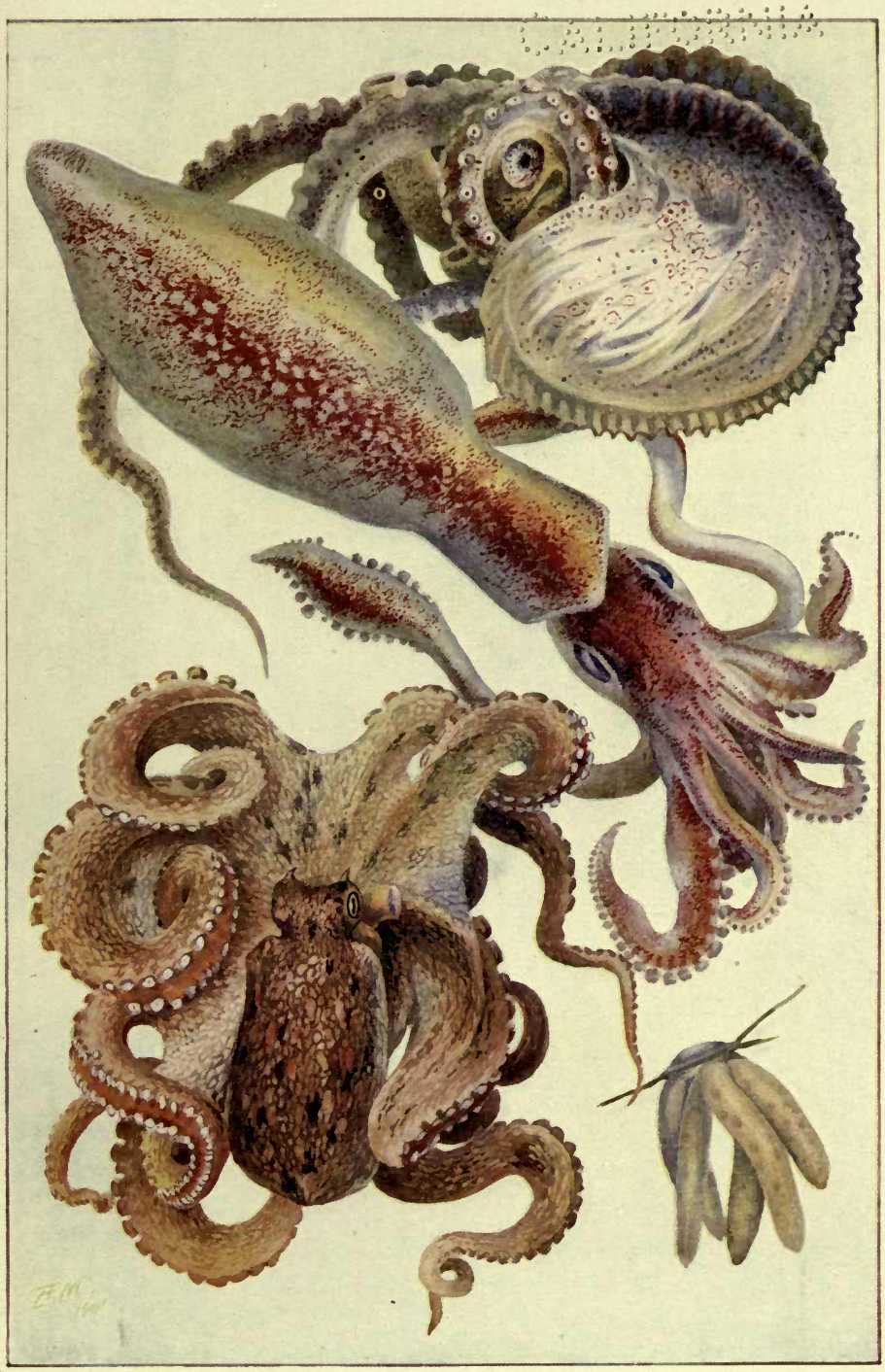


Fig. 522.—Dissection of a Cuttle-Fish (*Sepia*) from the back, to show interior of gill-cavity. The muscular mantle has been cut through and turned over to the right, and the tentacles have been cut short: X X (on mantle), two projections which "button" into two corresponding pits (X X) while water is being ejected through funnel; K K, kidney openings; *I. ap.* Intestinal aperture. Course of breathing-water shown by arrows.

UNIV. OF
CALIFORNIA



HEAD-FOOTED MOLLUSCS (CEPHALOPODS)

1. Paper Nautilus. 2. Squid. 3. Egg Capsules of Squid. 4. Common Octopus.

UNIV. OF
CALIFORNIA

Shell's gills. It is in fact a case where efficiency has been gained by the suppression of some of the members of a series (see p. 384), those remaining becoming larger and more specialized. In an active rapacious animal like a Cuttle-Fish some special method of constantly renewing the water in the large gill-cavity is an obvious necessity, especially as all the waste products of the body (in addition to carbonic acid gas from breathing) are discharged into it. We find that the back wall of the cavity is extremely muscular, and during life contracts at regular intervals, as can readily be seen in an aquarium specimen, so as to force out the impure water and the various waste substances. These are expelled through a muscular tube, the *funnel*, pure water being admitted by the large slit already mentioned. As will be explained in another section, the waste water is ejected with such force through the funnel that it enables the animal to swim backward with great velocity. As in so many other cases, various organs of the body are always liable to have fresh duties imposed upon them, in addition to their own proper and original work. And as in the course of time such an organ often gives up the old work entirely, and devotes itself wholly to the new, we find that the animal kingdom presents numerous cases of "changes of function".

The breathing apparatus of the Pearly Nautilus (*Nautilus pompilius*) is a good deal like that of the Cuttle-Fish, but there are *four* gills instead of two, and the funnel is of simpler nature, consisting of two halves rolled together but not fused.

SNAILS AND SLUGS (GASTROPODA)

The typical SEA-SNAILS and SLUGS (marine Gastropods) agree to some extent with Cuttle-Fishes, for they have given up the series of gills which their remote ancestors probably possessed, and those which remain are sheltered in a comparatively spacious gill-cavity, into which all the waste products of the body are discharged. But as a consequence of an extraordinary twisting round of the upper parts of the body which has taken place, one result of which is the spiral shape of the shell, this cavity is placed in front, being so to speak over the shoulders, and opening by a large slit above the neck region. In some cases *two* gills are present, *e.g.* in the Ormer or Sea-Ear (*Haliotis*) (fig. 523), and the waste water makes its exit by a slit in the roof of the gill-

cavity, the position of which is marked by a row of holes in the shell. The Keyhole Limpet (*Fissurella*) possesses the same number of gills, and the water which has traversed the gill-cavity makes its way out by the hole at the top of the shell to which the common name of this form is due. There are two interesting relatives of this type which lead up to the arrangement described. In one of these (*Emarginula*) there is an exit slit at the front edge of the shell, while in the other (*Rimula*) there

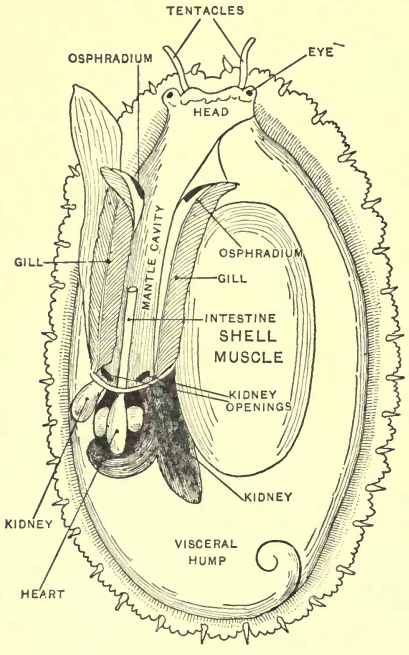


Fig. 523.—Ormer (*Haliotis*) seen from above after removal of shell. The gill-cavity has been opened.

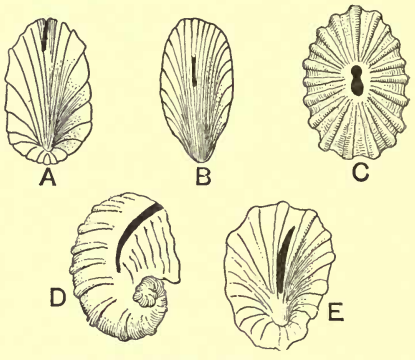


Fig. 524.—Shells of various Sea-Snails (seen from above)

A, Emarginula; B, Rimula; C, Fissurella; D and E, successive stages in growth of Fissurella.

is a hole placed a little way from the front (fig. 524). If the development of the Keyhole Limpet is traced it is found that there is first of all a slit at the front edge of the shell, then an opening rather farther back, and lastly the aperture at the top of the shell which characterizes the adult (fig. 524). This would certainly appear to be a case of recapitulation, in which the life-history of the individual epitomizes the family history, and the two allied forms just described retain throughout life what were no doubt stages in the evolution of Keyhole Limpets.

Examination of a typical spiral sea-snail, such as the Whelk (*Buccinum*) or the Purple-Shell (*Purpura*), shows that only *one* gill is present, one member of the original pair having been sacrificed for greater efficiency, and this gill is placed very much to one side (fig. 525). Two gills probably blocked up the gill-

cavity to such an extent that regular entry and exit of water were interfered with, while the arrangement which has superseded the old one enables fresh water to flow up one side of the gill-cavity, over the single gill, and then down the other side, washing out the various waste products to the exterior. And in the carnivorous forms which have been taken as examples the entering water is provided with a special means of access in the form of a sort of tube or "siphon". The position of this is marked by a notch in the shell which, as noticed elsewhere (see p. 96), is characteristic of carnivorous snails, as compared with vegetarian forms which have no siphon, and therefore no notch to lodge it. The difference may be plausibly explained if we remember that carnivorous snails have to be specially active in order to get a living, and as activity is associated with properly-purified blood, we may expect such creatures to have more effective breathing arrangements than their more sluggish relatives which live on vegetable food.

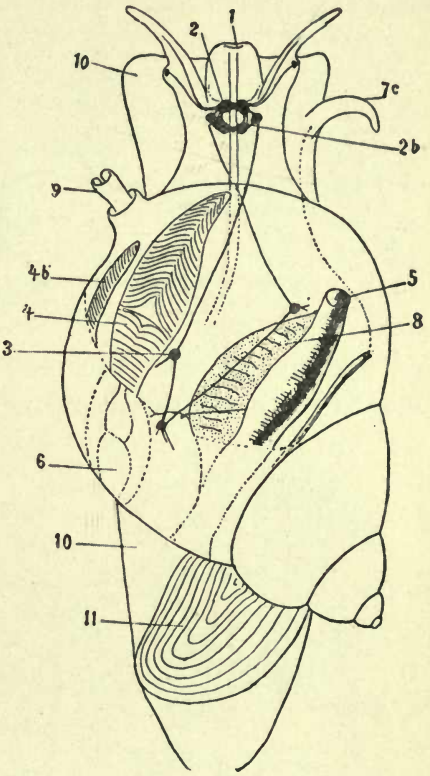


Fig. 525.—Diagram of a Whelk (*Buccinum*), seen from above. Shell removed and the roof of gill-cavity supposed transparent. 1, Mouth; 2, brain-ganglion; 2*b*, nerve-cord connecting side-ganglion (above) with foot-ganglion (below); 3, one of the three ganglia on the twisted nerve-loop; 4, gill; 4*b*, osphradium; 5, opening of intestine; 6, heart in pericardium; 8, a gland (purple-gland in Purpura); 9, siphon; 10, 10, foot; 11, operculum.

The breathing organs of the Common Limpet (*Patella vulgata*) are in a particularly interesting condition. If we remove the large conical shell which covers the back of this animal, and look for a gill-cavity in the position where it is found in a Whelk or Purple-Shell, we shall readily discover it, though in size it is comparatively small. On opening this cavity, however, no gill is to be found, although some not very distantly-related forms, as, *e.g.*, John Knox's Limpet (*Acmæa testudinalis*), possess one well-developed gill in this position (fig. 526). Careful examination

of the floor of the Limpet's gill-cavity shows the presence of a minute orange-coloured projection on either side, and the position

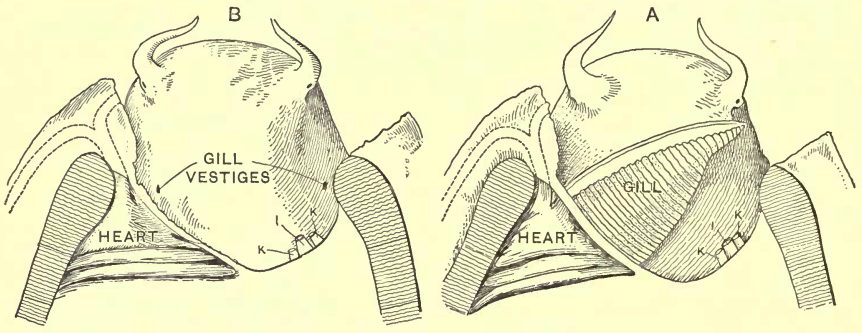


Fig. 526.—Gill-cavities of John Knox's Limpet (A) and Common Limpet (B) enlarged, as seen from above with roof removed. I, Intestinal aperture; K K, kidney apertures

and nerve-supply of these prove them to be the vestiges of two gills which ancestral Limpets no doubt possessed (fig. 526). How then does a Limpet breathe? The answer is, that it has developed new gills for itself of quite a fresh kind, in the form of a large number of little plates which grow out from the

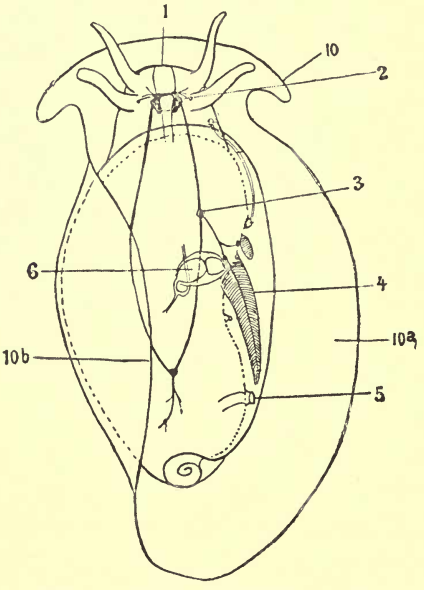


Fig. 527.—Diagram of Sea-Hare (*Aplysia*), seen from above

1, Mouth; 2, nerve-ring with ganglia; 3, one of the two ganglia on the untwisted nerve-loop; 4, gill, just in front of which is seen the osphradium; 5, opening of intestine; 6, heart in pericardium; 10, 10*a*, right parapod; 10*b*, left parapod folded over back.

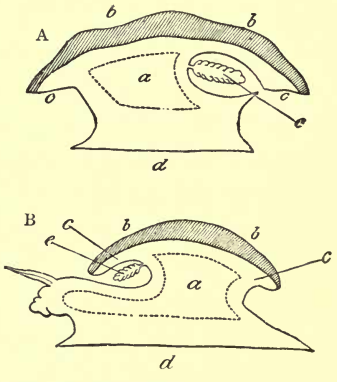


Fig. 528.—Diagrammatic cross section of Hind-gilled Snail (A), and longitudinal section of Fore-gilled Snail (B). *a*, Space occupied by internal organs; *b b*, shell; *c c*, mantle; *d*, foot; *e*, gill in gill-cavity.

mantle-skirt that runs right round the body (as in a Mail-Shell) and overhangs the foot. These *mantle-gills* are very

conveniently situated, being washed with sea-water whenever the tide is up.

So far we have considered the Fore-gilled Sea-Snails, in which the gill-cavity has been brought right round to the front, as the result of twisting, and the gill or gills which it usually contains are therefore in *front* of the heart, which they supply with pure blood. But in the Hind-gilled Sea-Snails the upper part of the body has begun to twist back again (in the direction of the hands of a watch) so that the gill-cavity has shifted from the front to the right side of the body. This is the case, for example, in the curious slug-like Sea-Hare (*Aplysia*), where the laterally-placed gill-cavity contains a single gill which is now placed rather *behind* the heart (figs. 527 and 528). This group of Molluscs also includes the Sea-Slugs proper, which have struck out a line of their own, and have lost shell, gill-cavity, and typical gills. Some of them, however, have been enterprising enough to grow new gills, just as the Limpet has done. Of this a good example is the Sea-Lemon (*Doris*), in which a beautiful circlet of feathery gill-plumes is situated far back on the upper side, surrounding the opening of the intestine (fig. 529). Although these have no gill-cavity to shelter them they are well-protected, for they can be drawn back into a groove until no trace of them can be seen from the outside.

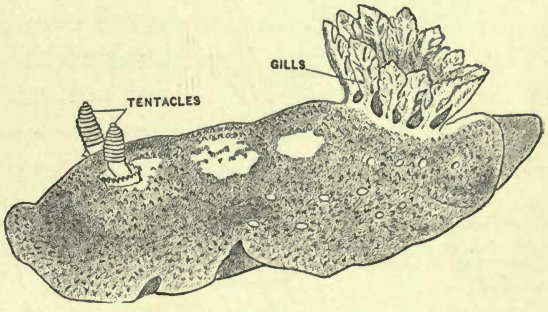


Fig. 529.—Side view of Sea-Lemon (*Doris*)

Other Sea-Slugs (as *Elysia*) are content to breathe with the general surface of the body, and this method appears to purify the blood sufficiently in a large number of thin-skinned animals belonging to diverse groups, especially when they are of small size. This is partly dependent on the fact that the smaller the animal the larger the surface of the body relative to its bulk, besides which none of the organs are very far removed from the surrounding medium, and consequently have but little difficulty in exchanging their waste carbonic acid gas for oxygen.

BIVALVE MOLLUSCS (LAMELLIBRANCHIA)

Bivalves possess well-developed breathing organs, as may readily be seen by even a superficial examination of any common form. If we take, for example, a Mussel, Cockle, or Oyster, we shall find the body covered by a pair of strong calcareous plates, which are the halves of the bivalve shell, and are placed on the right and left sides of the body. These valves cover, and indeed are chiefly secreted by, two flaps of the body-wall, constituting together the mantle-skirt. If a human being were clothed in a coat so large that its sides completely covered his body, head, and limbs, he would serve as a rough model of the arrangement—that is, if one could imagine the coat to be a part of him and not merely an investment. These two large mantle-flaps of a bivalve do a considerable amount of the work of breathing, and if one of them be lifted up a large plate-like *gill* will be seen beneath it in any one of the three common types named (fig. 530). These gills, the shape of which has suggested the name of the group (Lat. *lamella*, a thin plate; Gk. *branchia*, gills), share the work of breathing with the mantle-flaps, and are usually regarded as equivalent to the two plume-like gills of a cuttle-fish or ormer. We have seen (see p. 248) that bivalves are in some respects degenerate, and depend for food upon ciliary currents, which carry minute organisms to the mouth. Both mantle-flaps and gills are richly covered with cilia, and act as current-producing organs, thus enabling feeding and breathing to go on, and also providing for the removal of products of waste when the animal is buried in sand or mud, with only the hinder end projecting (fig. 531). We

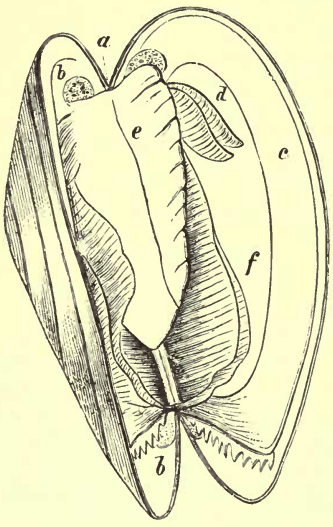


Fig. 530.—Freshwater Mussel (*Anodonta*) opened and seen from below

a, Position of mouth; *b b*, adductor muscles (which keep shell closed) cut through; *c*, mantle lobe; *d*, labial palps or feelers; *e*, foot; *f*, left gill.

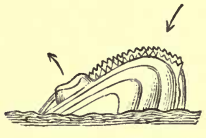


Fig. 531.—Freshwater Mussel (*Anodonta*) embedded obliquely in mud, with hinder end projecting. The arrows indicate the currents of water which enter and leave the mantle-cavity

may therefore correlate the large size and great complexity of the gills of freshwater mussels, &c., with the fact that they do double duty, like the pharynx of a Lancelet or an Ascidian (see p. 389).

The plate-like gills of a Freshwater Mussel are remarkably complex, constituting the last term of a series to which arrangements found in other bivalves lead up. The simplest case is that of certain forms (*Nucula*, &c.), where either gill consists of an axis bearing a double series of little flattened outgrowths. An advance upon this is seen in the Saltwater Mussel (*Mytilus*), for here the little outgrowths are represented by long threads, which turn up at their ends owing to the limited size of the gill-cavity. Adjacent threads are connected together by the interlacing of long cilia. Each gill of a Freshwater Mussel (fig. 530) consists of an outer plate and an inner plate. These have arisen by *fusion* of the outer and inner sets of filaments, which simply interlock in a Saltwater Mussel.

A few bivalves (*Cuspidaria*, &c.) have modified in another way. The gill on either side is only represented by a horizontal perforated plate of muscular nature, which divides the gill-cavity into upper and lower compartments. In these forms the mantle-lobes must do most of the breathing work.

CHAPTER XXXIV

ANIMAL RESPIRATION—JOINTED-LIMBED ANIMALS WHICH BREATHE IN WATER

Two classes of Arthropods exemplify adaptations for breathing in water, *i.e.* Crustaceans and King-Crabs. And as in other groups of animals, the higher members are more specialized in regard to their breathing organs, as well as in other respects.

CRUSTACEANS (CRUSTACEA)

The HIGHER CRUSTACEA, such as Lobsters, Crayfish, Prawns, Shrimps, and Crabs, possess large and complex *gills*, all of which are borne on the thorax, or region which succeeds the head. The Common Lobster (*Homarus vulgaris*) is a convenient first example, and it may be premised that the eight pairs of limbs borne by its thorax are, beginning in front, three pairs of *foot-jaws* which help to tear up the food, the huge *pincers*, and four pairs of *walking-legs* (see vol. i, pp. 403–405). On first inspection no gills at all are visible, and this is because a special shelter has been provided for these delicate structures. There is, in fact, a spacious *gill-chamber* on each side of the body, covered by a large *gill-cover* extending down to the bases of the limbs. There is, however, a slit by which water can enter behind and below, and go out in front. On removing this protective covering (which recalls the gill-cover of a bony fish as regards its use) a number of large *gills* are seen (fig. 532). Each of them is like a bottle-brush (to use Huxley's simile), and consists of a central axis beset with numerous threads. On the outside are six *limb-gills*, attached to the bases of the last two pairs of foot-jaws, the pincers, and the first three pairs of walking-legs. On turning these back ten *joint-gills* are seen, attached in pairs to the junctions between the limbs and body from the last foot-jaws to the third pair of walking-legs,

inclusive. If these joint-gills are folded back in their turn, four *side-gills* become apparent, so called because they grow out from the side wall of the body. They correspond to the last four segments of the thorax, which bear the four pairs of walking-legs. Each limb-gill is associated with a plate-like outgrowth (*epipod*)

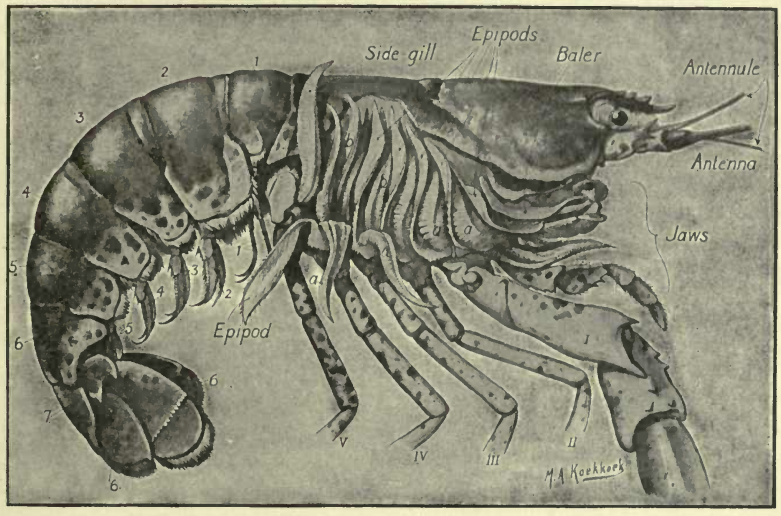


Fig. 532.—Gills of Right Side of Lobster (*Homarus vulgaris*), reduced.

The gill-cover has been removed, the pincers (I) and four walking-legs (II–V) cut short: 1–7, segments of abdomen and their appendages; *a a a a*, limb-gills (two last turned down); *b b*, joint-gills

from the limb to which it belongs, and the chief use of these plates appears to be to help to keep the gills separate, so that water may pass between them. From what has been said it will be seen that there are twenty gills in all on each side of the body, and this is most easily understood by presenting the facts, for one side, in a tabular form.

GILL-FORMULA OF LOBSTER (SIMPLIFIED AFTER HUXLEY).

Segments of Thorax.	Limbs.	Limb-gills.	Joint-gills.	Side-gills.
1	1st foot-jaw.	0	0	0
2	2nd „	1	0	0
3	3rd „	1	2	0
4	Pincers.	1	2	0
5	1st leg.	1	2	1
6	2nd „	1	2	1
7	3rd „	1	2	1
8	4th „	0	0	1
		6	+ 10	+ 4 = 20

The simplest way of explaining the many variations that are to be found as regards number among the gills of various Higher Crustaceans is to suppose that they are reductions of various extent on a primitive condition, in which each of the eight rings or segments making up the thorax carried four gills on each side of the body, *i.e.* one limb-gill, two joint-gills, and one side-gill, giving an original total of thirty-two. If this be the case, the Lobster has lost twelve gills each side, those that remain having become more efficient. This is the same principle on which the gills of fishes and of molluscs have already been explained (see pp. 393–394).

The forty gills of a Lobster present a very large surface for purification of the blood, but they would be of little use if there were not some efficient arrangement for renewing the water in the enclosed gill-chambers. There are no cilia, as in a Lancelet or Mussel, to cause a steady flow of water, and other means have therefore to be employed. The movements of the limbs, to which limb-gills and joint-gills are attached, must do something in this direction, and the more quickly a Lobster moves about the better they act. They are not able, however, to do more than stir up the water, without producing a steady current in a definite direction. Such a current does exist, the impure water flowing out steadily from the front of each gill-cavity, and careful observation of an aquarium specimen shows how this is brought about. Just at the front of each gill-chamber something will be seen in constant movement, and examination of a dissected Lobster shows that this something is the edge of a boat-shaped plate, the *baler*, which lies within the gill-chamber in front of the gills (fig. 532), and constantly scoops out the water, hence its name. The plate is part of the last of the three jaws belonging to the head (second maxilla), and during life these jaws are in constant movement from side to side, which of course keeps their baling plates working. Another very interesting device also deserves notice. It is extremely important for parasites and particles of dirt to be kept out of the gill-chamber, and this is managed to some extent by tufts of long hair-like bristles which are attached to the bases of some of the limbs, and strain the water as it enters the gill-chamber.

The Freshwater Crayfish (*Astacus fluviatilis*) has undergone greater reduction than the Lobster as regards its breathing organs,

for it possesses only eighteen gills each side, there being, for example, only *one* side-gill, the last of its series. But in front of this are two little threads placed where other side-gills are situated in the Lobster, and these are no doubt vestiges of such gills, which Crayfishes once possessed but have now all but lost.

A very large reduction has taken place in the Common Prawn (*Palæmon serratus*), for it has but eight gills each side, *i.e.* one limb-gill, two joint-gills, and five side-gills. In spite of the reduction it will be seen that it possesses one more of the last kind than the Lobster. It is also to be noted that the Prawn's gills, instead of being like bottle-brushes, are plume-shaped, consisting of a central axis bearing two sets of leaflets, much as in the typical gill of a Sea-Snail (see fig. 523, p. 394).

Some of the Prawns and Shrimps use the first walking-leg for cleaning the gills, pushing it into the front end of the gill-chamber for this purpose.

The Common Hermit-Crab (*Pagurus Bernhardus*) cleans its gills by means of the last pair of walking-legs, which are small, and, like the pair in front of them, find their chief use in holding on to the shell in which their owner lives.

Crabs constitute the most highly specialized of all the groups of Higher Crustaceans, and exhibit a large amount of reduction and modification in their breathing organs. The most typical species, of which we may take the Edible Crab (*Cancer pagurus*) as a type, are shore-forms, which spend a good part of their time out of water, so that special provision is necessary to prevent their gills from drying up by exposure to the air. On examining the type mentioned we shall find that the gill-cover is in such close contact with the bases of the limbs that water cannot enter the gill-chamber from behind or below, as in the Lobster and its allies. There is a special aperture in front for this purpose, which can be closed when necessary by a sort of door or valve constituted by a part of the last pair of foot-jaws. Waste water is scooped out by the baler through two other openings situated still farther to the front. On opening one of the gill-chambers seven large plume-gills are at once visible, of which five are joint-gills, while the other two are equivalent to the first two side-gills of a Lobster. There are also two limb-gills belonging respectively to the second and third foot-jaws. There is no gill attached to the first foot-jaw, but it possesses a large plate or epipod (belong-

ing to a vanished gill), which is long and curved and can be moved over the outer surface of the gills, serving apparently to keep them clean (fig. 533). The epipods of the second and third foot-jaws project back under the gills as "churning rods", helping to maintain the circulation of water.

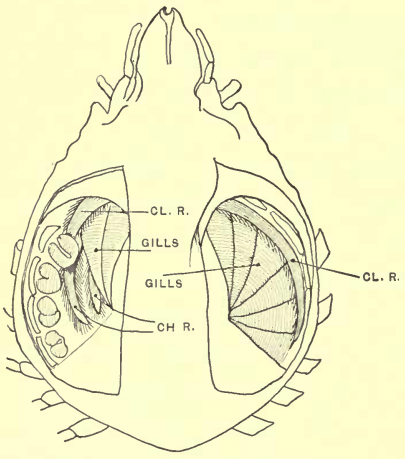


Fig. 533.—Gills of a Crab

The roofs of the gill-chambers have been removed and four gills cut short on the left side: CL.R., cleaning-rods (epipod) of first foot-jaws, the left one is cut short; CH.R., churning rods (epipods) of second and third foot-jaws.

In the Mantis-Shrimps (*Squilla*, &c.) the tail or abdomen is of relatively large size, and tufted gills are borne by the outer parts of its limbs (fig. 534). It is a much simpler arrangement than those so far described.

Sessile-eyed Crustacea, in which the eyes are devoid of stalks, are divided into Amphipods, flattened from side to side, and Isopods, flattened from above downwards. In the former group are included the little Sand-Hoppers (*Talitrus*, &c.) and their allies, in which the gills are simple plates carried on the inner sides of the limbs of the thorax (fig. 534). The attenuated Skeleton-Shrimps (*Caprella*) practically consist of head

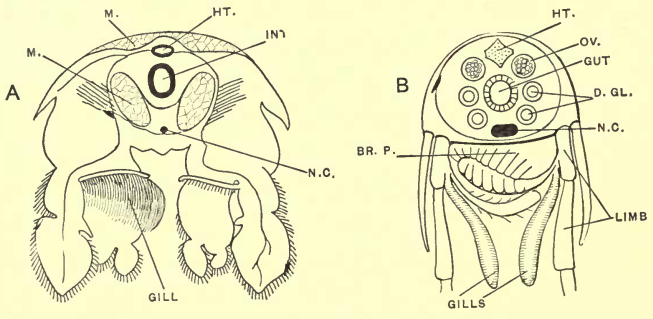


Fig. 534.—Gills of Mantis-Shrimp and Sand-Hopper

A, Cross section through tail of a Mantis-Shrimp (*Squilla*), showing a gill on one side and a gill-axis on the other. B, Cross section through thorax of a Sand-Hopper (*Gammarus*), showing a pair of gills. BR.P., Brood-pouch; D.GL., tubular digestive glands; HT., heart; INT., intestine; M.M., Muscles; N.C., nerve-cord; OV., ovaries.

and thorax only, the abdomen being reduced to a mere stump. The thorax is made up of eight rings or segments (of which the two first are fused with the head), which is the typical number

for a Higher Crustacean, and a pair of large rounded gills are borne on the fourth and fifth of these.

In Isopods, such as the Sea-Slaters (*Idotea*, &c.) and the Water Wood-Louse (*Asellus*), the gills are delicate plates borne on the inner sides of the abdominal limbs, the outer parts of which protect them to some extent.

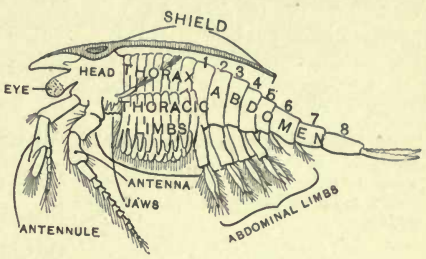


Fig. 535.—Mud-Shrimp (*Nebalia*), enlarged

Left half of shield cut away. The letter o in THORAX is placed on the cleaning filament of the second jaw.

Mud-Shrimps (*Nebalia*, &c.) breathe by means of eight pairs of flattened limbs borne on the thorax. These are protected by a large thin shield, which grows back from the head over this part of the body. The second jaw on each side bears a flexible whip-like filament, by means of which the breathing-limbs are cleaned (fig. 535).

Many of the LOWER CRUSTACEA are of small size, and breathe entirely or largely through the general surface of the body, wherever the protective layer (cuticle) that covers the skin is thin enough to permit of this. Special gills may, however, be present in some cases, as in the larger members of the Leaf-footed Crustacea (Phyllopods) such as Apus and Branchipus. These possess very numerous delicate flattened limbs, each of which carries a soft rounded gill. In Apus a protective shield grows back from the head (as in a Mud-Shrimp) and covers a large part of the body, and the inner side of this shield probably helps in the work of breathing. The small Phyllopods known as Water-Fleas (*Daphnia*, &c.) are distinguished by the shortness of the body, which, except the head, is enclosed in a bivalve shell quite comparable in nature to the shield of Apus. There are a few pairs of flattened limbs, without gills, and these by their constant movement keep up a stream of water between the halves of the shell, the inner surface of which shares with them the work of breathing.

The little Mussel-Shrimps (Ostracods) breathe much in the same way as Water-Fleas, but the bivalve shell is of greater relative importance, and encloses head as well as trunk. The limbs are narrow and specialized, and do not present the large breathing surface possessed by the leaf-shaped appendages of

Phyllopods. The second jaw belonging to the head (first maxilla) is provided with a large fan-like plate which by its movements helps to maintain a stream of water through the space between the halves of the shell (fig. 536).

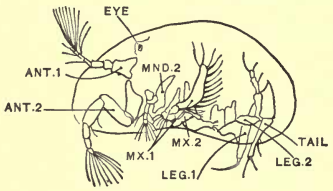


Fig. 536.—A Mussel-Shrimp (*Cypris*), enlarged. ANT.1, Antennule: ANT.2, antenna; MND., mandible; MX.1, first maxilla (notice the large fan-plate); MX.2, second maxilla.

In Barnacles (Cirripedes) the long tendril-like feet which fish for food (see p. 254) probably assist in breathing, which is also partly carried on by the soft fold of skin that lines the shell-plates on either side. In Acorn-Barnacles (Balanidæ) there is a folded projection between each of these flaps and the bases of the limbs, which probably acts as a gill.

KING-CRABS (XIPHOSURA)

The curious King-Crabs (Limulus) that shuffle about on the surface of mud, devouring worms, &c., are protected by strong shield-armour, through which breathing cannot take place. Specialized gills are therefore present, and are well protected, as the habits of their owners would otherwise render them liable to be soiled with mud. On examining the under side of a King-Crab, a broad plate, the gill-cover (operculum), will be seen behind the last pair of walking-legs (fig. 537). There is good reason for thinking that this plate has been formed by the fusion of two flattened limbs. Behind it may be observed the projecting edges of the five pairs of abdominal limbs, which also are plate-like, and bear on their upper sides (so as to be well protected) a large number of delicate gill-folds (fig. 537), arranged somewhat like the leaves of a book, and offering a large surface

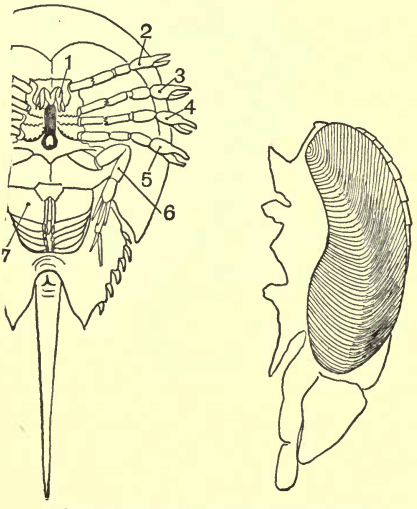


Fig. 537.—King-Crab (*Limulus*), reduced

On the left the under side is represented and on the right an abdominal limb with its gill-folds. 1, Cheliceræ; 2–6, legs. The mouth is seen as a darkly-shaded slit between the bases of the legs; 7, operculum.

to the water which surrounds them. The gill-cover and the gill-bearing limbs can be moved by special muscles so as to renew the breathing-water from time to time.

CHAPTER XXXV

ANIMAL RESPIRATION—LOWER INVERTEBRATES WHICH BREATHE IN WATER

SEGMENTED WORMS (Annelids)

The most interesting members of this group, so far as the present section is concerned, are to be found among the Bristle-Worms (Chætopoda), and after first considering these it will be necessary to add a little regarding Leeches (Discophora).

BRISTLE-WORMS (Chætopoda)

The marine Bristle-Worms (Polychætes) include both actively carnivorous forms which have no fixed abode, and also tube-dwellers, although there is no sharp boundary between the two sub-groups. The skin is in all cases sufficiently thin to be of use in breathing, and the surface offered for this purpose is increased by the presence of numerous pairs of hollow foot-stumps, the organs by which burrowing, crawling, and sometimes swimming are effected. There may, however, be special respiratory organs on the upper side of the body, and these not infrequently take the form of branching gills. In certain flattened forms (Polynoids) there is a double series of thin scales (elytra) on the back, and these would appear to answer the same purpose (fig. 538). Such scales may be visible externally, but in the Sea-Mouse (*Aphrodite*) they are enclosed in a sort of gill-chamber, which is roofed over by a felt-work of minute bristles cemented together.

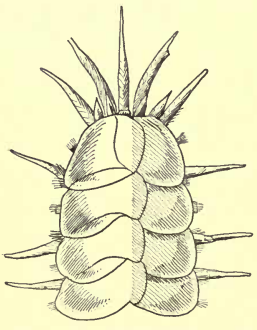


Fig. 538.—Scale-Worm (*Polynoë*). Front end seen from above, to show breathing-scales.

The Lugworm (*Arenicola*), which lives in a burrow in the sand, is a sort of transitional case between those marine bristle-

worms which rove from place to place and the greatly specialized tube-dwellers. It possesses delicate branching gills along part of its upper surface (fig. 539). But in cases where there is a definite dense-walled tube of lime, or horny matter, or sand-grains and the like cemented together, it is clear that the trunk-region is unfavourably situated for breathing, whether by its general surface or by means of special outgrowths. It is not, therefore, surprising to find in such cases that the head bears gills, generally in the shape of a pair of large feather-like plumes covered with cilia (*Terebella*, *Sabella*, *Serpula*, &c.) (fig. 540). Currents of water are set up by the action of the cilia, and these not only constantly renew the water necessary for breathing, but also wash away waste-products, and keep up the supply of food (see p. 258). It is interesting to note that these structures present another instance of "change of function", being, in fact, old organs put to a new use, and corresponding to a pair of little projections (palps) possessed by the head of an ordinary marine worm where they are concerned with touch, and perhaps other senses as well.

Fig. 539 Lugworm (*Arenicola piscatorum*), reduced. To show the feathery gills.

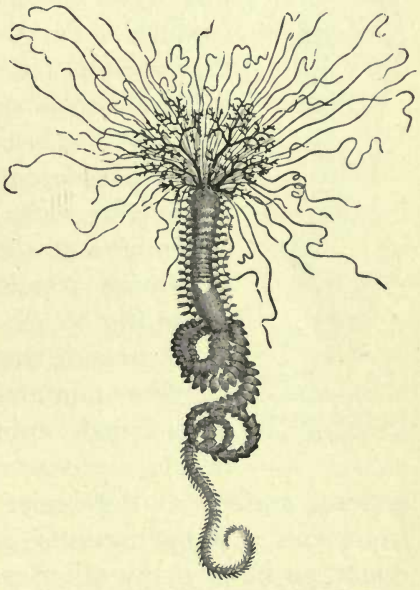


Fig. 540.—A Tube-Worm (*Terebella*), showing gill-plumes on head

LEECHES (DISCOPHORA)

In most Leeches the soft moist skin is sufficiently effective as a breathing organ without the aid of gills, and it is very richly provided with blood-spaces, many of which are unusually near the surface. There is nothing very extraordinary in this, for

breathing organs of all kinds must of necessity be closely related to the blood-system.

There is, however, a marine leech (*Branchellion*), living as a parasite upon the Torpedo, which possesses gill-tufts reminding one of an arrangement common among marine bristle-worms.

SIPHON-WORMS (GEPHYREA) AND WHEEL-ANIMALCULES (ROTIFERA)

SIPHON-WORMS do not as a rule possess special gills, but breathe by means of the skin. In forms like the Bristle-Tail (*Echiurus*) and Bonellia (see p. 150), where there is a projecting proboscis in front of the mouth, it is probable that this organ is concerned with breathing as well as with feeding. In the sand-swallowing Siphon-Worm (*Sipunculus*) (see p. 259) the mouth is surrounded by a horse-shoe-shaped fold with a folded edge, and it is likely that breathing is one of the uses of this fold. Quite a different arrangement is found in an allied form (*Priapulus*) in the shape of a deeply-lobed appendage at the hinder end of the body, and which is almost certainly to be regarded as a breathing organ (fig. 541). Siphon-Worms also breathe in part by means of the digestive tube.

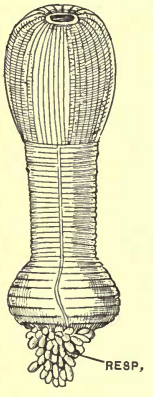


Fig. 541.—Priapulus (reduced). RESP., Breathing organ at hinder end of body.

The minute WHEEL-ANIMALCULES, like many other small animals, do not require anything elaborate by way of gills, and breathe through the general surface of the body. The ciliated wheel-organ at the front end sets up currents in the surrounding water, which no doubt, as in so many other cases, not only bring food but also the oxygen necessary for respiration. In those Wheel-Animalcules which live in cups or tubes the wheel-organ is particularly large and often complicated, reminding us of the large complex gills which are borne upon the heads of certain tube-worms (see p. 409).

MOSS-POLYPES (POLYZOA) AND LAMP-SHELLS (BRACHIOPODA)

The members of both these groups have already been adduced as instances of animals which feed by means of ciliary currents

(see p. 243), the current-producing organs in either case being a more or less complex plume in the neighbourhood of the mouth. These organs are no doubt also effective for breathing purposes. In Moss-Polypes something of the kind is clearly necessary, for although in these colonial animals each individual is of small size, and might perhaps be expected to breathe by means of the general surface, a large part of this is prevented from doing respiratory work. For every member of the colony is to a great extent enclosed in a horny cup, which is an effectual hindrance to exchange of carbonic acid gas for oxygen, and the soft part of the body which projects from the cup would not give a sufficiently large breathing surface were there not special outgrowths from it (see p. 261).

Lamp-Shells are solitary animals of much larger size than the individual members of Moss-Polype colonies, and it is therefore not astonishing that there should be outgrowths from their bodies which serve as gills, though (as in Moss-Polypes) these outgrowths play a double part. Nor must it be forgotten that the body of one of these animals is covered and protected by a firm bivalve shell, which in one sense diminishes the surface available for breathing. This, however, is compensated by the fact that each half of the shell is lined by a thin flap of the body-wall which takes part in the work of respiration. Although Lamp-Shells are but very distantly related to Bivalve Molluscs, there is a curious similarity between the two groups as regards feeding and breathing (see p. 248). This is only one of very many cases in the animal kingdom where more or less similar organs have been independently evolved in quite distinct groups, which have had, so to speak, the same physiological problem to solve.

ECHINODERMS (Echinodermata)

This large, important, and very sharply limited group or phylum of the animal kingdom includes Sea-Lilies (and Feather-Stars), Sea-Urchins, Star-Fishes, Brittle-Stars, and Sea-Cucumbers, besides other forms which have long been extinct. Two characteristics of these animals are especially noteworthy, as they largely influence the nature of the breathing organs and mode of breathing. They are: (1) A strong tendency to develop a firm protective armour, consisting of limy plates in the skin, often

united by their edges, and frequently bearing spines. (2) The possession of a set of tubes collectively known as the "water-vascular system", this name having been given because the system is connected with the exterior, for the purpose, it would

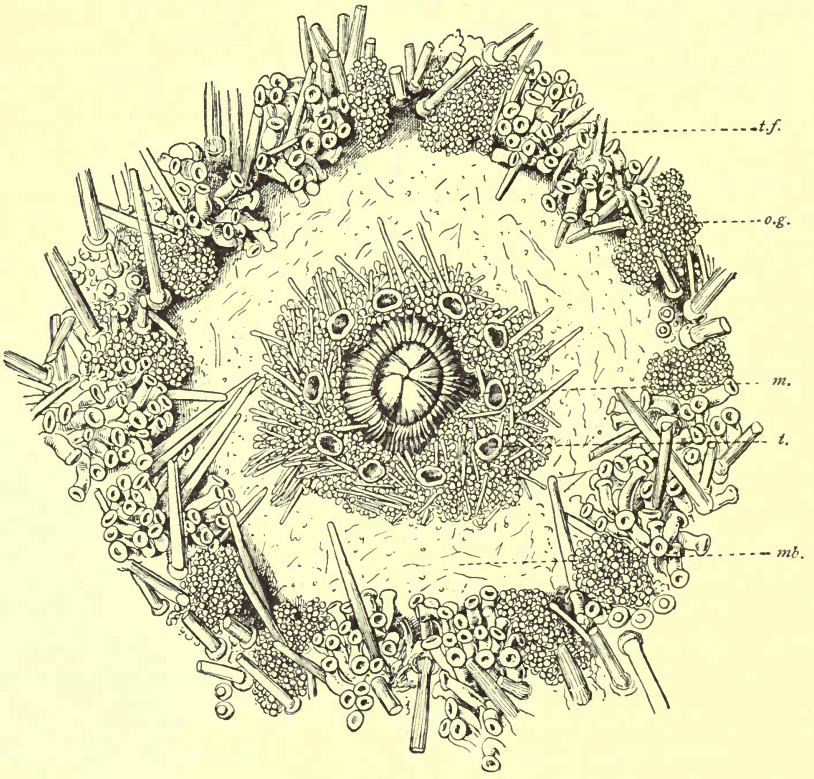


Fig. 542.—Mouth-area of a Sea-Urchin (*Echinus esculentus*), enlarged

m., Mouth with five teeth; *mb.*, membrane surrounding mouth; *o.g.*, an oral gill; *t.*, specialized tube-foot; *t.f.*, ordinary tube-feet.

appear, of taking in sea-water. The most important parts of the water-vascular system are a ring round the gullet, one or more canals by which this is connected with the outside of the body, and five branching tubes which it gives off to the "arms", rays, or equivalent parts of which the body largely consists.

INFLUENCE OF THE SKELETON ON THE DEVELOPMENT OF BREATHING ORGANS

It is quite evident that the possession of a firm external skeleton must more or less prevent breathing by means of the

general surface of the body, the limitation being greatest where the skeleton is best developed and most continuous.

Crinoids.—In a Feather-Star (*Comatula*) the body consists of a central cup, from the margins of which five branching feathery arms grow out. One side of the cup and the corresponding sides of the arms are strengthened by a continuous set of calcareous plates, through which breathing cannot take place. But the other side of the body, in the centre of which the mouth is situated, is covered by leathery skin, and it is necessarily this side which does the work of respiration, chiefly by means of special outgrowths, as will be explained later on. In Sea-Lilies it is usual for both sides of the body to be supported by firm plates, between which the soft breathing organs project.

In Sea-Urchins (Echinoids) the body is supported and protected by a firm test, composed of numerous calcareous plates united by their edges, and thus the area of the general surface available for breathing is very much reduced. The mouth, however, is situated in the middle of a soft membrane which no doubt partly performs this function, and its efficiency is greatly increased by the presence of five pairs of branched oral gills which project from it (fig. 542). The digestive tube is also specialized to assist in respiration, for part of the water which enters the mouth with food is conducted along a narrow tube ("siphon") that branches off from the gullet, and later on opens into the intestine.

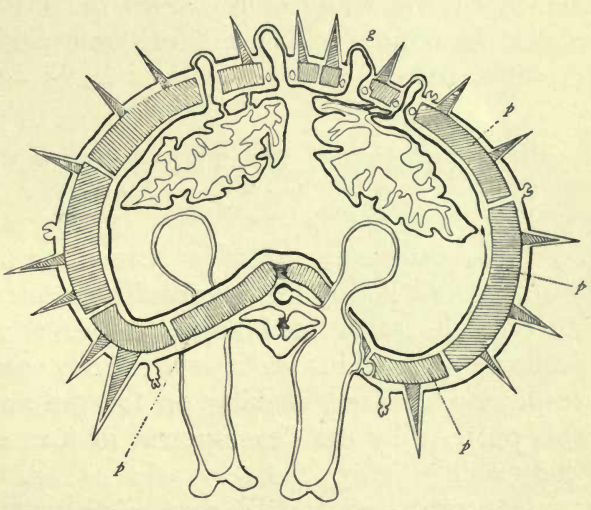


Fig. 543.—Cross section through Arm of Star-Fish enlarged
g, Gill; *pppp*, calcareous plates (hard parts are shaded obliquely). Two tube-feet are seen below

In ordinary Star-Fishes (Asteroids) the skeleton is not so complete as in the last group, so far as the upper surface and the sides are concerned, and numerous thin plates are left, from which small branching gills are protruded (fig. 543).

Brittle-Stars (Ophiuroids) are enclosed in very complete scale-armour, so that special provision for breathing is a necessity. There is a conspicuous swelling placed between the bases of every two adjacent arms, and each of these contains a couple of pouches opening by slits to the exterior. The ten pouches have a ciliated lining, by means of which sea-water is made to flow continuously through them for breathing purposes. And in some cases the slit-like opening is divided into two holes, one of which admits sea-water to the pouch, while the other serves as a means of exit.

Sea-Cucumbers (Holothurians) are leathery elongated forms in which the external skeleton is reduced to detached plates imbedded in the skin, so that a large part of the general surface is available for breathing. In many of these creatures there is a curious internal arrangement by which a great deal of the work of respiration is effected. There are here, in many cases, two large branched respiratory trees which open into the intestine (fig. 545), through the external opening of which water is alternately taken in and squeezed out, so that the large surface presented by the lining of the trees is constantly bathed with fresh water, enabling exchange of carbonic acid gas for oxygen to be readily carried on.

THE RELATION OF THE WATER-VASCULAR SYSTEM TO BREATHING

It is extremely probable that the water-vascular system as we now find it was first evolved as a means of breathing, for in all cases its radiating branches bear very numerous slender projections with thin walls, collectively presenting a very large respiratory surface, making up for the area rendered useless for this purpose by the development of firm calcareous plates in the body-wall.

Crinoids.—A typical case is presented by the Feather-Star (*Comatula*), in which five ciliated grooves run outwards from the mouth to send branches along the arms, and all their subdivisions. As described elsewhere, the small particles and organisms which constitute the food are conducted along these grooves to the mouth (see p. 265). Examination of any part of one of the arms shows that the food-groove which runs along it is flanked

on either side by very numerous groups of pointed structures, which are branches of the water-vascular system and act as gills. This affords another instance of water-currents produced by ciliary action having to do double duty, by bringing with them both food and oxygen. Breathing is effected similarly in the fixed Sea-Lilies, which are the most typical members of the group to which the Feather-Stars belong.

The delicate outgrowths just described are also of use as sense organs.

In ordinary STAR-FISHES (Asteroids) the water-vascular system, though retaining its uses in regard to breathing and sensation, has also acquired a new function, for it is here the means of locomotion. The remote ancestors of these creatures were almost certainly fixed forms (as Sea-Lilies still are), and when these became free some means of moving about had to be evolved, one solution to this problem being found in the way indicated. On the under side of a Star-Fish five broad grooves are to be seen, radiating from the mouth, and protruding from these are numerous tube-feet, equivalent to the delicate projections which flank the food-grooves in a Feather-Star. The walls of these tube-feet are sufficiently thin to act as gills, though, as we have seen, they are not the only, nor probably the chief, organs of respiration in this case (see p. 413).

SEA-URCHINS (Echinoids). — In an ordinary regular Sea-Urchin (see vol. i, p. 456) of spheroidal shape there are tube-feet comparable to those of a Star-Fish, but in this case arranged along five bands which stretch from one pole of the sphere to the other. They can be protruded beyond the tips of the spines so as to enable the animal to walk or climb, and they share the work of breathing with the oral gills and the soft membrane surrounding the mouth (see p. 413).

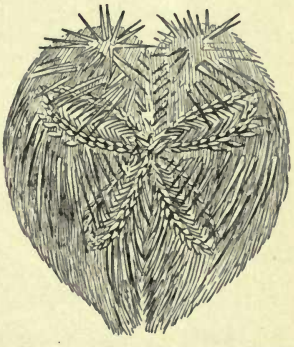


Fig. 544.—Upper Side of a Heart-Urchin (*Spatangus purpureus*), showing tube-feet specialized as gills and arranged like the petals of a flower.

Many of the Sea-Urchins, however, are of "irregular" shape, being more or less flattened and markedly two-sided. One result of this has been that the tube-feet present on the upper half of the animal have become useless as locomotor organs. But they have not been allowed to remain idle, for their value as breathing

organs has increased and they have become more or less specialized gills (fig. 544), branched in some cases so as to give a larger surface.

The structures which correspond to tube-feet in BRITTLE-STARS (Ophiuroids) project from the sides of the arms, and are of no use for locomotion. They probably assist in breathing to some small extent, but their chief use is to act as sense organs.

Most of the SEA-CUCUMBERS (Holothurians) are provided with tube-feet which help the other breathing organs present, but they

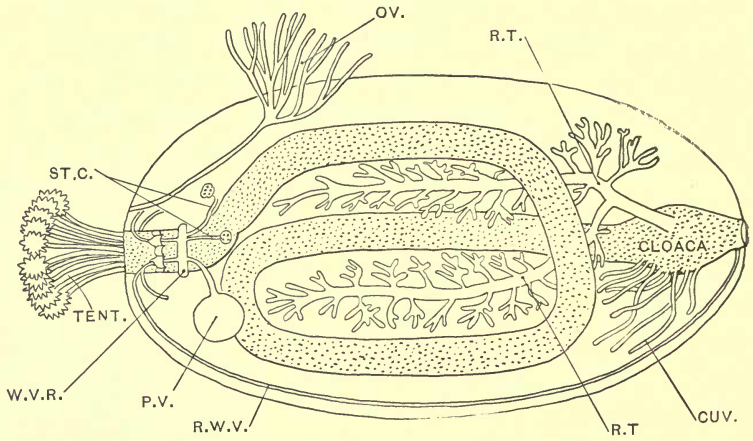


Fig. 545.—Dissection of Sea-Cucumber (diagrammatic)

The water-vascular ring (W.V.R.), bearing stone-canals (ST.C.) and Polian vesicles (P.V.), sends branches to the tentacles (TENT.), and gives rise to five longitudinal radial vessels (R.W.V.) which bear tube-feet not shown in figure); R.T., R.T., the two respiratory trees opening into CLOACA; CUV., Cuvierian organ, from which sticky defensive threads are ejected.

are not so important in this respect as the circlet of tentacles at the front end of the body, which also contains branches of the water-vascular system (fig. 545).

ZOOPHYTES (Cœlenterata)

The Hydroid Zoophytes, Jelly-Fish, Sea-Anemones, Corals, and Comb-Jellies which make up this large subdivision of the animal kingdom breathe by the general surface of the body, and the mouth is often surrounded by one or more circlets of tentacles, which, while their main use would appear to be to secure food (see p. 156), also largely increase the area over which breathing can take place. This is particularly necessary in those cases where there is a firm skeleton by which more or less of the surface of the body is prevented from taking part in respiration.

In the Organ-pipe Coral (*Tubipora musica*), for instance, each member of the colony lives in a tube, from which only the mouth-end can be protruded, and it is the external surface of this end which probably does most of the breathing. The eight broad feathery tentacles which surround the mouth largely increase the available area, and they are beset with cilia which set up currents by which the water in contact with them is constantly renewed.

Examination of fig. 416, p. 162, which represents one of the free-swimming Compound Jelly-Fishes (*Physophora*), will show that the numerous and diversely-shaped members of which the colony consists present collectively a very large external surface over which breathing may take place. At the top is a float, below this a stalk-like part on which are arranged numerous swimming-bells, and under these come a circlet of leaf-shaped structures, which cover feeding individuals, from which numerous long branched fishing-lines trail in the surrounding water.

It must further be remembered that the great diversity of animals included in the group of zoophytes are to all intents and purposes living stomachs of more or less complexity, and, since a great deal of water is taken in with the food, the lining of the large internal digestive space is able very materially to help on the respiration. Indeed it may be remarked generally that in the lower groups of the animal kingdom division of physiological labour is not effected to anything like the same extent as in the higher groups.

In some of the Sea-Anemones there is a special arrangement promoting very greatly the internal breathing above described. For, as in all zoophytes, the mouth is not precisely equivalent to the aperture so named in, say, an earth-worm, for it serves not only for the taking in of food, but also for casting out such portions of this as have not been digested. It is of slit-like shape, and leads into a gullet along which run a couple of ciliated grooves, one beginning at each corner of the mouth. Except when large prey is being swallowed or large undigested fragments passing out, the sides of the gullet are in contact and the central part of the mouth-slit closed. The ciliated

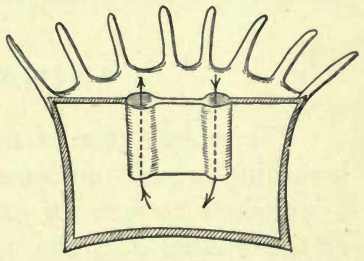


Fig. 546.—Diagrammatic vertical section of a Sea-Anemone, showing ciliated grooves of gullet. Arrows show the way in which currents of water flow in and out of the slit-like mouth.

grooves are thus converted into two ciliated canals, in one of which an inward current of sea-water is maintained, while the other is traversed by an outward current (fig. 546). The inflowing water carries with it not merely small organisms and particles which serve as food, but also dissolved oxygen which can be used for internal respiration.

SPONGES (Porifera) AND ANIMALCULES (Protozoa)

As explained in the preceding section, the body of a simple Sponge is shaped like a cup or vase with walls perforated by numerous holes (see fig. 265). By means of ciliary action sea-water is caused to stream continually through these holes into the central cavity, and thence to the exterior by the opening of the cup. In this way the animal, in spite of the fact that it is fixed, obtains an abundant food-supply together with plenty of oxygen, while at the same time all the products of waste are swept away. In the more complex Sponges, which are to a great extent colonial, the body is traversed by a labyrinth of canals, parts of which are ciliated, but the feeding and breathing arrangements are essentially the same as in the simple forms. Although no doubt the outer surface of a Sponge helps in breathing, it may be said that this function is chiefly performed by the internal surface, the area of which is greatly augmented when the canal-system is complex.

ANIMALCULES (Protozoa)

The minute size of these simplest animals renders specialized breathing organs unnecessary, since the outside of the body offers a sufficient surface for exchange of gases between the substance of the animal and the surrounding medium. In such cases as that of the Proteus Animalcule (*Amœba*) there is not even an external membrane to hinder diffusion of carbonic acid gas outwards, and oxygen inwards, and even where such an investment is present it is exceedingly thin. If, as an example of a fixed form, we take the stalked Bell Animalcule (*Vorticella*) it may be noted that the broad end of the body is provided with cilia, the currents set up by which provide both food and oxygen as in so many other cases.

In spite of what has been said it would appear that Protozoa also breathe to some extent by means of internal surfaces, for water is taken in with each portion of food, and this mixture of food and drink lies in a temporary hole (food vacuole) within the living substance of the body, which no doubt takes up dissolved oxygen from the watery part of it. The body also contains one or more clear fluid-filled spaces (pulsating vacuoles) which alternately increase and diminish in size, and have been proved in some cases to communicate with the exterior. It is usually held that this is a sort of pumping arrangement, of respiratory nature, whereby pure water containing plenty of dissolved oxygen is taken into the body, and impure water containing waste products ejected to the exterior.

CHAPTER XXXVI

ANIMAL RESPIRATION—BACKBONED ANIMALS WHICH BREATHE IN AIR

We have now seen that animals which breathe in water may use for this purpose various surfaces of the body, both external and internal, and that the larger and more complex forms augment the area afforded by the external surface by developing outgrowths known as *gills*. These vary greatly in shape, and are situated in various places. When they are large and complicated, it is usual to find special arrangements for sheltering them, and also for maintaining a constant flow of water over their surface.

The higher classes of the Backboned Animals (Vertebrates), *i.e.* Mammals, Birds, and Reptiles, live mostly on the land, and take in ordinary air for breathing purposes, which, after some of the oxygen has been absorbed from it, is again passed out, heavily charged with two of the waste products of the body, carbonic acid gas and water. The essential nature of the process is precisely the same as in those animals which breathe in water, but these use the oxygen which is dissolved in the surrounding medium. An animal that uses ordinary air for breathing purposes, and which, for brevity's sake, we may call an "air-breathing" animal, relies in most cases upon part of its internal surface, and backboned forms which do this mostly possess *lungs*, *i.e.* hollow outgrowths from the under-side of the throat-region (pharynx) of the digestive tube, by which the internal breathing surface is augmented. These structures are therefore in a way comparable to gills, which are also a device for increasing the area over which respiration can take place.

It is almost if not quite certain that land animals are descended from aquatic forms which breathed the oxygen dissolved in the surrounding water, and in the higher backboned animals the proof of this is unusually clear and particularly striking. If, for example, we examine an embryo chick, taken, say, from an egg upon which

the hen has brooded for three days, it will be quite easy to make out on the side of the neck-region several slit-like openings (visceral clefts) that communicate with the pharynx, and between which are thickened bars (visceral arches). These are undoubtedly equivalent to the gill-clefts and gill-arches of a fish, for they are situated in exactly the same place, and develop in precisely the same way, although the clefts are never of use for breathing purposes, and gill-folds do not grow out from them. In fact they soon close up, leaving no obvious trace that they ever existed. (See also p. 381.)

THE ORIGIN OF LUNGS

We have seen that there is considerable ground for the belief that gill-pouches in fishes and the like have probably been evolved from pouches on the side of the pharynx which originally performed some other function (see p. 382). And the modification of old organs into structures having a new use is such a frequent occurrence that we may well enquire if the lungs of backboned animals have not been made out of pre-existing structures, as

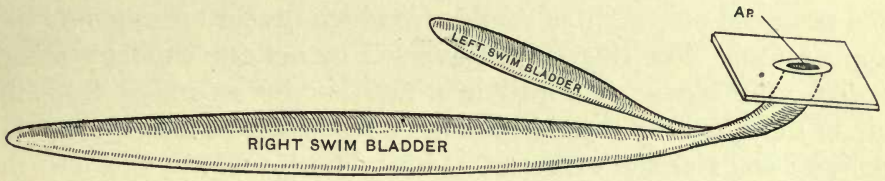


Fig. 547.—Swim-Bladder of Bichir (*Polypterus*), reduced and diagrammatic. AP., Aperture on floor of pharynx leading into swim-bladder.

have the gill-pouches which they supersede. Since Fishes correspond in a broad way to the aquatic ancestors of land-vertebrates, it is among them we must seek evidence as regards the evolution of lungs. Many Fishes possess a *swim-bladder*, containing air and developed as an outgrowth from the front part of the digestive tube. Although its primary use is to help in floating and balancing the body, it is known in some instances to assist the breathing, and it seems a likely enough organ to undergo modification into a lung. In the Bichir (*Polypterus*) of the Nile the swim-bladder is *double* (fig. 547) and grows out from the *under* side of the digestive tube, characters which make it more lung-like than that of most other forms, in which it is usually *single* and grows out of the *upper* side of the gut.

Indeed it must not be rashly assumed that the swim-bladder of one fish is of necessity precisely equivalent to the swim-bladder of any other form. The best evidence to be obtained in support of the view indicated as to the origin of lungs is presented by the remarkable Lung-Fishes (*Dipnoi*), of which more will subsequently be said. These creatures possess not only efficient gills, but also a swim-bladder into which ordinary air is taken for breathing purposes, the purified blood being returned direct to the heart, just as in the case of an ordinary lung.

Accepting the mode of origin of lungs just outlined, we may next enquire how these organs become more and more complex as we follow them up from Lung-Fishes to Amphibia, and thence to the thorough-going land-groups of Reptiles, Birds, and Fishes.

LUNGS OF AMPHIBIANS (Amphibia)

Taking the Common Frog (*Rana temporaria*) as a good type, we find that its lungs are a pair of simple elastic bags, which can be distended to a considerable size by the taking in of air. The surface presented by their lining is to some extent increased by the presence of a number of ridges, which give a honey-comb-like appearance. The ridges are traversed by delicate capillary blood-vessels, the blood contained in which is only separated from the air in the lungs by the thin lining of those organs and the equally delicate walls of the vessels. Hence diffusion of oxygen into the blood, and of carbonic acid gas out of it, easily takes place.

We have seen that in the case of gills the maintenance of a stream of pure water over the breathing surface is provided for in a number of ways. Renewal of air in a lung is a matter of equal importance, and the manner in which it is brought about varies in different groups. As regards the Frog, it is of importance to notice that in this animal the feeding and breathing tracts are to some extent separated, though the arrangement is not so perfect as in the cases of the Lancelet, Tunicates, and the Acorn-headed Worm (see p. 389), where breathing-water and feeding-water are largely kept apart. It is a general rule among backboned animals where lungs are present, for the air used in breathing to pass through the cavities of the organs of smell, and we see the beginning of this in Lung-Fishes, where these organs not only possess *external* nostrils (the only nasal openings present

in ordinary fishes), but also *internal* nostrils, placed just within the upper lip. It is clearly advantageous for a land-animal to take in air through the nose, for food is often detected by smell, and this device increases the chance of finding it. In a Frog the internal nostrils open rather further back than in a Mud-Fish, and the external nostrils are valvular. The chief agency by which air is taken in and passed out is found in the muscular floor of the mouth, which is moved alternately up and down. The procedure adopted is somewhat as follows. The mouth being closed, its floor is lowered, when air passes through the nose into the mouth-cavity, after which the valvular nostrils are shut. The floor of the mouth is now raised, and the air is forced into the lungs. The blood in these organs having been purified to some extent, the floor of the mouth is again lowered, and the impure air is drawn out of the lungs into the mouth-cavity. The tip of the snout is next bent down a little so as to open the external nostrils, the mouth-floor is raised, and the air forced out through the nose to the exterior.

The Frog is only partially adapted to a life on land, being dependent upon a damp surrounding atmosphere, and, taking advantage of this, it has retained, or perhaps reacquired, the old method of breathing by means of the external surface of the body as an accessory to the more specialized respiration effected by lungs.

In the snake-shaped Cæcilians only one lung is properly developed, for two efficient organs of the kind could not be packed into the narrow body.

It is interesting to notice, in passing, that some Salamanders have specialized on quite different and very extraordinary lines in regard to respiration. Their peculiarity consists in the fact that they have abandoned lung-breathing altogether, for their lungs are either entirely absent or else reduced to useless remnants, while at the same time the structure of the heart has undergone a corresponding change. How breathing is carried on under such circumstances is not definitely known, but the skin, the lining of the mouth and pharynx, and the lining of the intestine have all been suggested as the parts which supply the place of the absent lungs. The pretty little spectacled Salamander (*Salamandrina perspicillata*) of Northern Italy will serve as an example of these lungless Amphibians.

LUNGS OF REPTILES (Reptilia)

Reptiles (as also Birds and Mammals) have abandoned skin-breathing, and rely entirely upon their lungs, which in the smaller members of the class, such as many Lizards, resemble in structure those of the Frog. But in the larger Lizards, Turtles, Tortoises, and Crocodiles these organs have become more complex, with the object of providing a larger breathing surface. Instead of a simple honey-combing of the internal surface, complex folds have come into existence (fig. 548). In this way the wall of the lung has become more or less spongy, with corresponding reduction of the central cavity. A new method of renewing the air in the lungs has also come into existence, for well-developed ribs are here present, attached to a breast-bone below, and jointed on to the backbone above. By muscular action the ribs and breastbone can be swung forwards and downwards, so as to increase the volume of the front part of the body, by which air is caused to flow into the lungs. When the muscles concerned cease to contract, these parts move back, mainly as a result of elasticity, to their original position, and the impure air passes out to the exterior. It may, then, broadly be said that renewal of air in the lungs depends in Reptiles (as also in Birds and Mammals) on the mobility of the chest-region (thorax). In cases where the lungs are complicated and spongy the movements of breathing cause direct renewal of air in the larger passages only, that in the smaller ones being purified by diffusion.

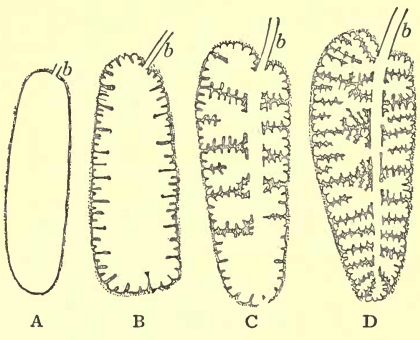


Fig. 548.—Diagrammatic longitudinal sections through Lungs, showing increase of breathing surface by ingrowth of folds; *b*, main branch of windpipe. A, Newt; B, Frog or small Lizard; C, Large Lizard or Tortoise; D, Turtle or Crocodile.

In an average Reptile the internal nostrils open further back than in Amphibians, and thus the feeding and breathing tracts are rather better separated. Crocodiles exhibit a great advance upon this condition, for the internal nostrils do not communicate with the mouth-cavity at all, but with a pharynx (fig. 549), into the floor of which the top of the windpipe projects (see p. 70),

and which is separated by a fold from the mouth-cavity. The mouth can therefore be kept open under water without fear of

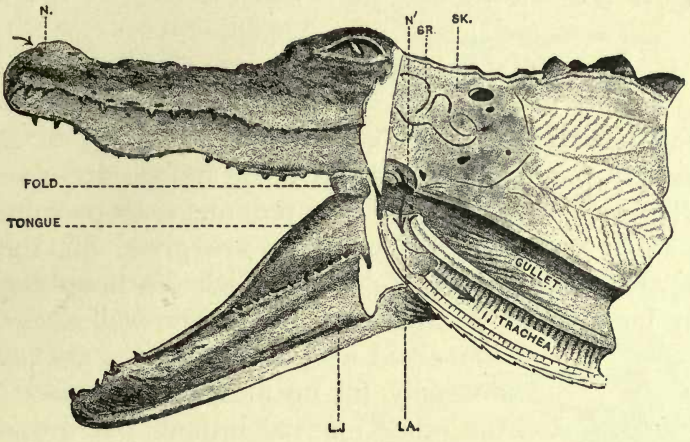


Fig. 549.—Head of Crocodile to show Breathing Arrangements, hinder part in section

BR., Brain; LA., larynx; L.J., lower jaw; N., external nostril; N'., internal nostril; SK., skull. Course of air entering lungs shown by arrows.

suffocation by entry of water into the lungs. The external nostrils are valvular, and close when their owner sinks below the surface.

Curious modifications of the breathing-organs are found in Snakes. As in the snake-like Amphibians (Cæcilians), the left lung is reduced to a mere vestige, the right lung being correspondingly enlarged. The reason for this arrangement would appear to be the same in both cases, *i.e.* adaptation to the shape of the long narrow body. An ordinary Snake feeds on living animals of relatively large size, and, to prevent choking while the tedious process of swallowing is going on, the end of the windpipe is drawn out into a projecting tube which protrudes from one side of the mouth.

Snake-like Lizards (*Amphisbænæ*), like true Snakes, possess but one fully-developed lung, that of the right side.

Fig. 550.—Lungs of a Chameleon, showing outgrowths. TR., Windpipe (trachea).

The lungs of Chameleons (fig. 550) suggest the arrangements that Birds possess in a much more elaborate condition, for the hinder portions of them grow

out into slender thin-walled *air-sacs*, which penetrate between the other organs of the body. How far these organs are of use in breathing is not known.

LUNGS OF BIRDS (Aves)

Although richly supplied with blood, the lungs of Birds are comparatively small, and instead of being mobile are closely fixed to the ribs and backbone. From the main air-passages which traverse them very complex branches are given off, the linings of which are raised up into folds by which the breathing surface is greatly increased. A number of large thin-walled *air-sacs* are connected with the lungs (fig. 551), and these not only fill up most of the space between the other internal organs, but are also, as a rule, continuous with air-spaces in the bones. How far purification of the blood takes place in the neighbourhood of these air-sacs is doubtful, but in any case it would appear certain that their presence conduces to the rapid and frequent flow of air through the main channels of the lungs, and hence promotes rapid breathing. It has been explained elsewhere that only Birds and Mammals among backboned animals are hot-blooded, maintaining a constant temperature whatever may be that of their surroundings (see pp. 208, 244). In these two groups the problem of adapting to lung-breathing requirements a heart and blood-vessels inherited from gill-breathing ancestors has been for the first time solved, and the impure blood poured into the heart from the general body is kept separate from the pure blood which that organ receives from the lungs. Hence increased activity, associated with more efficient breathing, one manifestation of which is a higher body-temperature. Birds are more active than Mammals, and it is not therefore surprising that they possess hotter blood (103° to 104° F. as against about 98° F.).

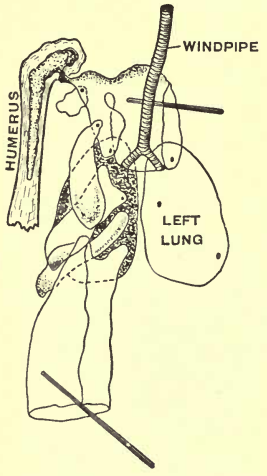


Fig. 551.—Lungs and Air-sacs of a Bird, seen from under side. The air-sacs of only one side are shown, and two of them have been cut through and rods pushed into them.

The relation of air-sacs to flight will be considered in another section. As to the means by which air is caused to enter and

leave the breathing organs, it need only be said that the arrangement is much the same as in Reptiles (see p. 424) when a bird is standing or walking, but during flight it would appear that the breastbone is relatively fixed, while the hinder part of the backbone is moved up and down. The same end is effected in either case.

Owing to the length of a bird's neck the windpipe is correspondingly elongated, and in some cases (Cranes) it is thrown into a number of loops situated in the breastbone (fig. 552). No plausible explanation has been offered as to the use of this peculiar arrangement, but it is difficult to believe that it has not some special meaning.

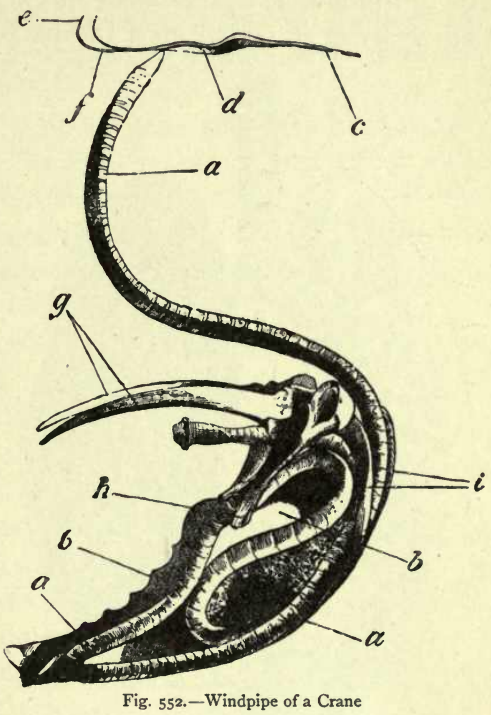


Fig. 552.—Windpipe of a Crane

aaa, Windpipe; *bb*, breastbone; *cdef*, hyoid bone (which supports tongue); *gg*, shoulder-blades; *h*, right coracoid bone; *i*, merry-thought.

LUNGS OF MAMMALS (Mammalia) (see vol. i, p. 45–47)

The lungs of a Mammal are very complicated spongy organs which fill most of the thorax (fig. 553). The windpipe divides into two branches, as a general rule, one for each lung. If one of these is traced it will be found to branch in a tree-like way, the smallest, very thin-walled branches being known as bronchial tubes. Each of these ends blindly, swelling up into a little bunch of air-cells, the walls of which are invested by a net-work of capillary blood-vessels. It is in these air-cells that the blood is purified, and they present collectively an enormous breathing surface. In short, the spongy lung of a Mammal is a very perfect contrivance for packing into a comparatively small space an extended area over which exchange of gases between the impure blood and the air can readily take place. Amphibians, Reptiles,

and Mammals form a series of increasing complexity in this respect, keeping pace, as it were, with increasing need for rapid oxygenation of the blood, which is most marked in the highest animals. Another series is constituted by the breathing organs of Amphibians, Reptiles, and Birds, culminating in the last, which surpass even Mammals as regards respiratory efficiency. They have, however, as we have seen, specialized on rather different lines.

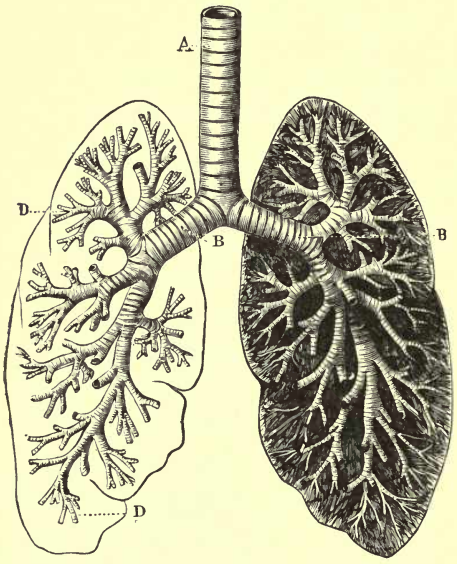


Fig. 553.—Air-passages of Lungs of Man

A, Windpipe; B B, bronchi into which this forks; D D, smaller air-tubes

As to the mechanical arrangements by means of which air is renewed in the lungs of Mammals, the movement of ribs and breastbone, so as to alternately increase and diminish the size of the thorax, takes place in much the same way as in Reptiles and Birds. There is, besides, a fresh factor of great importance in the midriff or diaphragm, a partition by which the cavity of the thorax is separated from that of the abdomen. This may be described as a thin, curved muscle, convex towards the thorax, and possessing a central tendinous part. There are also some strong bundles of muscle, the "pillars" of the diaphragm, which run from the under side of the backbone in the region of the loins to the part of the midriff furthest from the breastbone. The volume of the thorax is increased in the direction of its length, and the taking in of air promoted, by the contraction of the muscular margin of the midriff and of its pillars, so that the edge of this partition becomes flattened. When the muscle ceases to contract, the midriff once more becomes convex towards the thorax, which therefore diminishes in volume, as a result of which expulsion of impure air from the lungs is greatly helped. Indeed the midriff is of the very greatest importance as a breathing muscle. Backboned air-breathers which are lower in the scale than Mammals possess an ill-developed equivalent, though this usually has nothing to do with breathing.

As in so many other cases, material already present has been modified so as to serve a fresh purpose. It is worth while to note here that the lungs of Mammals, like those of Amphibians and Reptiles, are very elastic, and are kept continually on the stretch. Their elasticity greatly aids in the expulsion of impure air from the breathing passages.

It would be a mistake to suppose that the breathing movements which the walls of the chest execute cause air to rush into the bronchial tubes and air-cells. It is only the air in the larger air-passages which is directly renewed in this way, while purification of the air in the smaller passages and their endings is brought about by gaseous diffusion.

In Amphibians, Reptiles, and Birds the breathing and feeding tracts are not very completely separated (except in the case of Crocodiles), but in Mammals they are much more perfectly marked off from one another. The internal nostrils do not open on the roof of the mouth, but into the pharynx (fig. 554). It may, in fact, be said that the two tracts cross one another in this part of the digestive tube, on the floor of which is the opening (*glottis*) which leads into the windpipe. Mammals also present a very characteristic arrangement by means of which food is prevented from getting into the breathing organs. For the front of the glottis is guarded by an elastic flap, the *epiglottis*, which during swallowing is folded back over the breathing opening, and constitutes, as it were, a sort of bridge over which the food passes back into the gullet. Human beings sometimes attempt to speak when this transit of food is in progress, with the result that the epiglottis springs up and particles make their way into the windpipe. This is what is popularly called "swallowing the wrong way".

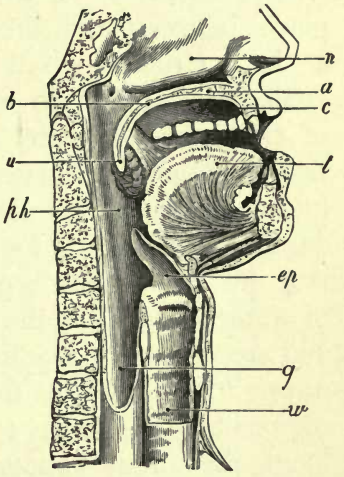


Fig. 554.—Mouth, Nose, &c., of Man, in vertical section

n, Cavity of nose opening into pharynx (*ph*), and separated from mouth-cavity by hard palate (*a*) and soft palate (*b*), the latter ending in a rounded projection (the uvula, *u*), below which is the opening between mouth-cavity and pharynx; *c*, roof of mouth; *t*, tongue; *ep*, epiglottis; *w*, windpipe; *g*, gullet.

It would scarcely repay us to consider in detail the various modifications which the breathing organs present in the various

subdivisions of the Mammals, but the order (Cetacea) which includes Whales, Porpoises, &c., is of special interest in this connection, and therefore merits a brief notice. Although these animals are obliged to come frequently to the surface in order to breathe or "blow", they can remain under water without inconvenience for between three and four minutes. It is not, therefore, surprising to find that their lungs are of large size, and it may also be noted that parts of the body-wall are richly supplied with elaborate net-works of blood-vessels aggregated into thick masses ("wonder-nets") which possibly serve as a means of storing purified blood, though this is only a conjecture. The midriff is very thick, and its central tendon comparatively small, and the unusually large amount of muscle present renders the movements of breathing particularly vigorous. The most remarkable peculiarity, however, is the very complete separation which takes place between the breathing and feeding tracts, pretty much as in a Crocodile (see p. 425), the object being similar, *i.e.* to enable the animal to open its mouth under water without risk of choking from entry of fluid into the air-tubes. The top of the windpipe is a projecting cone, the end of which fits closely into the back of the nasal passage, leaving, however, a space on either side by which food can travel on into the gullet. In order that the animal may breathe with as small a part of the body out of water as possible the nostrils are shifted to the top of the head, and are very close together, or even fused into one, constituting two or one "blowhole", as the case may be. When in the colder ocean regions a whale comes to the surface and breathes out air from its lungs, the watery vapour with which this is abundantly charged is condensed by the cold so as to become visible. This appearance has given rise to the common but erroneous idea that a whale "spouts" out of its blowhole the water that has been taken in at the mouth. Such a procedure would be impossible for anatomical reasons, and the superfluous water which is taken in with the minute animals that mostly constitute the food (see p. 29) really passes out at the sides of the mouth.

In the newly-born young of Pouched Mammals (Marsupials) such as Kangaroos, the breathing and feeding tracts are separated in much the same way as in the Whales and their allies, but for a rather different reason. Young Marsupials when they first come into the world are in an exceedingly immature and helpless con-

dition. They are placed by the mother in her pouch and affixed to the long teats there situated. As for some time they cannot even suck properly, the milk is forced into their mouths by the contraction of a sheet of muscle which covers the milk-glands, a procedure which would be pretty sure to cause suffocation were there not some mechanical device to prevent it.

CHAPTER XXXVII

ANIMAL RESPIRATION—BACKBONELESS ANIMALS WHICH BREATHE IN AIR

Having considered the backboned air-breathers, we now pass on to Molluscs, Arthropods, Worms, &c. which live on land or in fresh water, and use ordinary air in breathing, as contrasted with members of the same great groups that live in water, salt or fresh, and respire the air which is dissolved in this.

AIR-BREATHING MOLLUSCS (Mollusca)

The only subdivision of the Molluscs which contains air-breathing members is the class (Gastropoda) that includes Snails and Slugs of all kinds. The great majority of these are marine, but the order of Lung-Snails (and Slugs) has been established for the reception of most of the species which live on land or, it may be, in fresh water, and are collectively termed Pulmonates (L. *pulmo*, a lung), because they breathe air by means of an organ which may be called a "lung", though it is quite different in origin and nature from the lung of a backboned animal. There are also certain land-snails (*Cyclophorus*, *Cyclostoma*, &c.) which are not Pulmonates (though they breathe in a similar way), but belong to the Fore-gilled Gastropods (Prosobranchs).

We have seen (see p. 393) that in the marine Prosobranchs there is a cavity opening by a wide slit above the neck, and containing either two (Ormer and Keyhole Limpet) or more usually but one (Whelk and Periwinkle) plume-like gill. This is the gill-cavity, and its roof is the mantle, which may be regarded as a sort of flap that has grown out from the wall of the body. In an ordinary Limpet (*Patella*) the gill-cavity has lost both its gills, and is probably able, by means of its thin roof (which is richly provided with blood-vessels), to breathe the damp air which surrounds

the animal when it is uncovered by the tide. A Limpet, however, possesses special gills all round the body (see p. 396), which are used when the tide is up, and perhaps also breathe air when the tide is down. It is practically certain that some of the Land-Snails have sprung from ancestors which lived, like Limpets, between tide-marks, and were able to breathe both air dissolved in water and ordinary atmospheric air. Driven by keen competition from the shore, the descendants of these forms took to living altogether on dry land, and gave up breathing air dissolved in water, while at the same time their gill-cavities became specialized as air-breathing organs. Other Land-Snails probably took origin from estuarine or freshwater species, in which cases the still earlier ancestors were doubtless marine in habit.

Examination of a Garden-Snail (*Helix aspersa*), a common and very typical Pulmonate, shows the presence of a cavity opening above the neck, corresponding precisely to the gill-cavity of a Limpet both as to position and in regard to the complete absence of gills. This "lung", as it may be called for convenience sake, is of large size, and the inner surface of its thin roof (the mantle) is raised into a net-work of ridges (fig. 555) by which the surface exposed to the air is increased in area (compare p. 424). The muscular floor of the lung is curved, and by its movements brings about the passage of air into and out of the breathing cavity. The lung does not open in front by a wide slit, as did the ancestral gill-cavity to which it corresponds, but by a small round hole on the right-hand side. This narrowing of the external aperture is in order to prevent the lung from drying up, which would prevent it from performing its function, and by muscular action the comparatively small opening can be varied in size or even closed altogether according to circumstances.

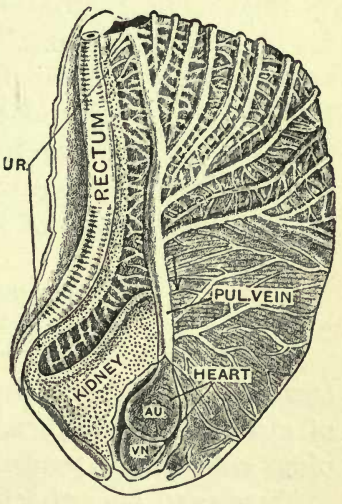


Fig. 555.—Roof of Lung of Land-Snail (*Helix*), showing inner surface (enlarged). Impure blood flows to the net-work of ridges and, when purified, is carried by the pulmonary vein (PUL.VEIN) into the auricle (AU) of the heart and thence to the ventricle (VN), which pumps it to the body; UR., ureter carrying waste from kidney and opening in front (upper end of figure) close to end of rectum.

Land-Slugs may be broadly described as flattened-out Snails,

and their breathing organs are constructed on the type just described. The movements of breathing can easily be watched in a living specimen of the common Black Slug (*Arion ater*), which is one of the species in which the shell has disappeared altogether. The lung is here rather small, and its boundary is marked by a different texture of skin. As breathing goes on the pulmonary aperture may be noticed alternately enlarging and narrowing.

Among the commonest air-breathing Snails living in fresh water are different species of Pond-Snail (*Limnæus*) and Trumpet-Snail (*Planorbis*). These and similar forms are obliged to come to the surface from time to time for the purpose of breathing.

AIR-BREATHING ARTHROPODS (Arthropoda)

The typical air-breathing classes of the Arthropods are:—(1) the one which contains only the widely-distributed and simply organized form Peripatus (Prototracheata), (2) Centipedes and Millipedes (Myriapoda), (3) Scorpions, Spiders, Mites, &c. (Arachnida), and (4) Insects (Insecta). There are also certain Crustacea which have taken to a life on land, and have therefore acquired the power of breathing ordinary air.

PERIPATUS (Prototracheata)

This creature possesses in their simplest form the air-tubes (*tracheæ*) which are the most characteristic respiratory organs of air-breathing Arthropods. Indeed, on this account, these are often collectively termed Tracheata.

Scattered over the body of Peripatus are a number of small holes (*stigmata*), some of which are arranged on either side in two rows, one above and the other between the stump-like legs. Each of these holes opens into a small cavity from which arise a number of delicate *air-tubes* that penetrate the body to some extent, the end gained being to supply oxygen to the different organs, and take away their carbonic acid gas together with some water vapour. By means of alternate contraction and relaxation of the muscular wall of the body the air in these tubes is from time to time renewed. The principle of this arrangement is quite different from that exemplified by the

lungs of backboned animals and land-snails. For, as we have seen, there is marked centralization in the case of these organs, impure blood flowing to them for purification, after which it is distributed to the body at large. Air-tubes effect the same purpose by decentralization, carrying air to and from the different organs. In Peripatus the breathing organs are not very perfect or specialized, but they are an early step in the evolution of a mode of respiration which reaches its highest expression in insects. We have no certain knowledge of the way in which air-tubes first took origin, but it is extremely likely that they are modifications of structures which originally served some other purpose. Peripatus resembles segmented worms (annelids) in several respects, and it is pretty certain that the ancestral forms from which arthropods have been derived were segmented, more or less worm-like creatures. It is therefore among annelids that we must look for the organs which by change of function have become air-tubes. Now the skin in such worms contains numerous *glands*, by which various sorts of material are separated from the blood for various purposes, such, *e.g.*, as the formation of tubes in which to dwell. And it has been suggested that air-tubes have arisen from branched skin-glands which gave up their original function and were specialized for carrying oxygen to the body.

CENTIPEDES AND MILLIPEDES (MYRIAPODA)

The openings (*stigmata*) into the system of air-tubes by which a Millipede or Centipede breathes are placed in two rows, one along each side of the body. The remote ancestors from which these forms are descended probably resembled Peripatus in many respects, and no doubt possessed stigmata scattered over the body, as well as some with a more regular arrangement (see p. 434). Later on many of these were done away with, only a row along each side being retained, as most conveniently situated. This is another instance of the principle already illustrated by the cases of gill-slits (see p. 386) and teeth (see p. 14), where greater efficiency is obtained by reduction in number of structures, which are in the first instance numerous and unspecialized. We shall have occasion to see that among Insects the reduction of these particular organs is carried a great deal further. Each

of the breathing-pores of a MILLIPEDE opens into a small air-cavity, from which a bundle of branching air-tubes penetrates into the adjacent parts of the body in a much more thorough way than in Peripatus. These air-tubes are also much more definite in nature than in the last-named animal, and each of them has a firm elastic lining possessing a spiral thickening, the object of which is to give flexibility and prevent collapse of the walls of the tube. Indistinct traces of such a thickening are seen even in Peripatus. The same end is served in fire-hose and the like by insertion of a spiral wire into the cavity of a flexible tube, so that the flow of water may not be interrupted by any accidental kink. The object in the air-tube is of course to secure a continuous passage of air.

CENTIPEDES are much more active creatures than Millipedes, and therefore require more perfect arrangements for purification of the blood. The breathing-pores open as before along the sides of the body, where the body wall is much softer than it is above and below, in which regions the skin is covered by a strong horny layer. The pores are less numerous and more specialized than in a Millipede, and the air-tubes which are connected with them ramify through the body in a more thorough way. The bunches of air-tubes are also more or less united by connecting tubes, so as to form a continuous system, and this considerably promotes the circulation of air.

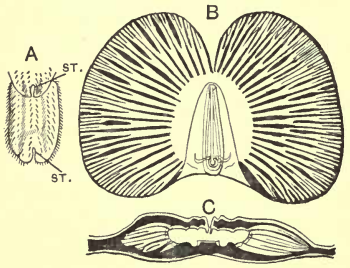


Fig. 556.—Breathing Organs of Shield-bearing Centipede (*Scutigera*)

A, Two of the shields, slightly enlarged, showing breathing-pores (ST. ST.). B and C, A lung-sac from above and in vertical section, considerably enlarged—the blood-space surrounding the sac is represented in black.

The breathing organs of the greatly specialized Shield-bearing Centipede (*Scutigera*), a very active long-legged creature, with a short body, differ greatly from those found in ordinary Millipedes and Centipedes. There are eight shield-like scales on the upper side of the body, and at the hinder end of each of these (except the last) is a slit which leads into what may perhaps be called a *lung-sac* (fig. 556). This is a flattened bag suspended in a blood-space, and giving rise on either side to some 300 branched air-tubes, separated only by their thin walls from the surrounding blood, which it is their office to purify. The arrangement is specially interesting, because it resembles

to some extent the breathing apparatus which is characteristic of Scorpions, of which details will be given later.

It is noteworthy that in animals which breathe by air-tubes the blood-system is in a comparatively ill-developed condition, although the other organs of the body may be exceedingly complex and specialized. For while irregular blood-spaces of different size are found in all parts of the body, there is not, as one might perhaps expect, an elaborate set of blood-vessels, but only a heart and, it may be, some exceedingly delicate arteries which soon merge into the blood-spaces. The heart is often called the *dorsal vessel*, being a long thin-walled tube running near the upper surface of the body. Its sides are provided with numerous pairs of valvular openings through which blood enters. The imperfect state of the blood-system is related to the exceptional nature of the means by which respiration is effected. In, say, a fish one great use of the heart and vessels is to pump blood to the breathing organs for purification, but this arduous kind of work is unnecessary in a centipede or insect, for the air-tubes of these creatures carry pure air to all parts of the body, so that the blood of any organ gets rid almost immediately of any carbonic acid gas which it may have evolved, and at the same time the corresponding loss of oxygen is made good. The organs of circulation are therefore relieved of a large amount of work, and the chief duty which remains to them is that of carrying nutritive material through the body for repair of waste and promotion of growth, a duty which can be carried out sufficiently well without an elaborate system of blood-vessels.

INSECTS (INSECTA) AS AIR-BREATHERS

In the case of typical insects the breathing-pores are comparatively few in number, and open into an exceedingly complex system of air-tubes, which permeate all parts of the body. The arrangement has already been briefly described for the Cockroach (see vol. i, p. 348), in which each of the last two segments of the thorax and first eight segments of the abdomen bears a pair of pores—ten pairs in all. The arrangement of some of the larger air-tubes will be gathered from fig. 557. The internal organs have a silvery appearance when immersed in water, and this is caused by the air contained in the minute breathing-

tubes which ramify on and within them. Looked at under the microscope these present a very striking appearance. The breathing-pores are valvular, and provided with minute muscles by which their size is regulated, it being possible to close them altogether. The contents of the air-tubes are expelled by the contraction of muscular bands that stretch from the upper to the lower side of the body, which is therefore flattened when they come into action. On these muscles ceasing to contract, the body resumes its former shape as a result of elasticity, and air is consequently drawn into the breathing-tubes. But if the breathing-pores kept fully open all the time air would only be renewed in the larger air-tubes, while the minute branches would have to rely upon diffusion for the purification of their air. This, however, is not the case, for competent authorities state that the breathing-pores are closed for part of the time the breathing-muscles are acting, so that air is forced into many of the small air-tubes, the contents of which are thus directly renewed. This is strikingly in contrast to what happens in the lung of a human being or other higher vertebrate, where the smallest air-spaces are of such a delicate nature that they would be liable to injury if currents of air constantly passed in and out of them, and which therefore get rid of their carbonic acid gas and keep up their supply of oxygen by gaseous diffusion. As even the minutest branches of the insect's air-tubes are furnished with a firm elastic lining they are not so liable to injury by a tidal movement of air, such as must take place when air is forced into them, and later on squeezed out again. The view is here taken that air-tubes serve for getting rid of carbonic acid gas as well as for the introduction of fresh oxygen, but some zoologists maintain that only the latter purpose is served by them. It must, indeed, be confessed that our knowledge of the breathing of insects is very imperfect, and in this, as in so many other directions, there is abundant scope for research upon the physiology of lower forms.

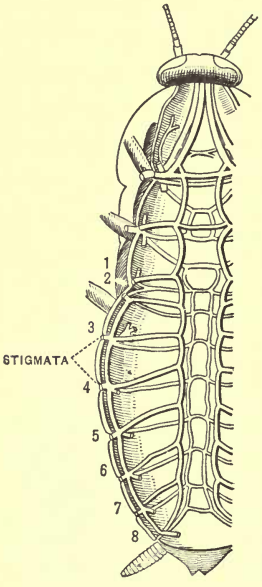


Fig. 557.—Dissection of Cockroach (*Periplaneta orientalis*), from above, to show chief air-tubes (enlarged); 1–8, segments of abdomen.

There is a very interesting kind of modification observable in the breathing organs of Insects, such as Bees and Locusts, which possess the power of rapid flight, for in such cases the air-tubes swell into a varying number of *air-sacs* (fig. 558), the result being to give the body a larger bulk in proportion to its weight than would otherwise be the case. This is curiously reminiscent of the state of things in Birds, where the lungs communicate with a system of large air-sacs, and in both kinds of animal the use of the arrangement is to be sought in connection with the power of flight, which will be discussed in a later section. But it must not be supposed that the air-sacs are equivalent in the two cases, for the lungs and air-sacs of Birds arise by outgrowth from the digestive tube, while the air-tubes and air-sacs of Insects develop in the first instance as simple in-pushings of the skin, which gradually become more and more complicated until the adult condition is reached.

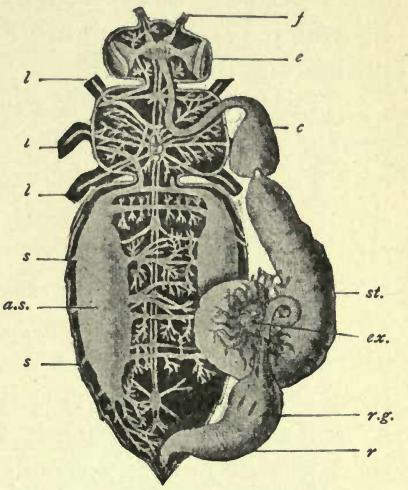


Fig. 558.—Dissection of Honey-Bee (*Apis mellifica*), enlarged

s s, Two of the breathing-pores (stigmata), *a.s.*, air-sac, with which numerous branching air-tubes are connected; *f*, feeler; *e*, eye; *l l l*, legs; *c*, crop; *st.*, stomach; *ex.*, excretory tubes; *r*, rectum; *r.g.*, rectal glands.

Air-breathing Aquatic Insects.— Some Insects live in water during part or all of their existence, in spite of which they may be dependent upon ordinary air for breathing purposes. Special devices are then generally present, having relation to the aquatic habit. The Great Water-Beetle (*Dytiscus*), for example, lives entirely in the water during the larval part of its life, and mostly so when adult. The elongated predaceous larva has but one properly developed pair of breathing-pores, placed at the tip of the tail, which is from time to time protruded from the water to allow air to enter the respiratory tubes. This is facilitated by the presence of numerous hairs at the hinder end of the body, causing this region to float up more readily than the head end. The adult Beetle is furnished with a full complement of breathing-pores, which open above into a space of which the floor is formed by the upper side of the body, and the roof by

the wing-cases. This space serves as a reservoir for air, which the beetle carries about with it under water, and renews from time to time by coming to the surface and pushing out the hinder end of its body. At the same time air is taken into the last pair of breathing-pores, which are much enlarged and equivalent to those present in the larva.

The little Whirligig Beetles (*Gyrinus*), which may often be seen moving about in an erratic manner on the surface of ponds and streams, are in the habit of diving when alarmed, carrying down a bubble of air with them which enables breathing to go on during submersion, and prevents water from getting into the breathing-pores. The Great Black Water-Beetle (*Hydrophilus piceus*) lives under water, and carries air about in a manner different from that described for *Dytiscus*. A large part of the body is covered with closely-set down, in which air is entangled, so that the breathing-pores are kept dry and are able to carry on their work. This air, of course, requires renewal from time to time, and there is a remarkable kind of adaptation by which this can be managed without the Beetle having to leave the water. For the ends of the feelers (antennæ) are broad and hairy so as to fit them for acting as ladles, by means of which air-bubbles are dragged under water and applied to the downy surface of the body, to which they adhere.

Interesting breathing arrangements are found in some of the Water-Bugs, which are either purely aquatic or live chiefly on the surface. Pond-Skaters (*Hydrometridæ*) are of the latter kind, and almost everyone must have seen them moving swiftly about in the way that has suggested their name. Like the Whirligig Beetles, they are able to dive, at which time they are completely surrounded by a film of air, which sticks closely to the velvety surface of their bodies. It is, however, easy to drown them. The Water-Boatmen (*Notonectidæ*), which swim actively about on their backs, are also provided with an arrangement of hairs, enabling them to carry a supply of air under water.

The ravenous Water-Scorpions (*Nepidæ*) are thoroughly aquatic in habit. Both in the broad flat kind (*Nepa*) and the lean hungry-looking one (*Ranatra*) the only breathing-pores present are placed at the tip of the tail, from which projects a long narrow tube composed of two closely-interlocking halves. It is supposed that the tip of this organ is protruded from time

to time at the surface for the purpose of taking in air, but the details have not yet been made out.

Fig. 559.—The Drone-Fly (*Eristalis tenax*) and its larva, the Rat-tailed Maggot

The larvæ of a great many Two-winged Insects (*Diptera*) live in water, and in many cases come to the surface to breathe air. It is then usual to find a breathing-tube at or near one end of the

body, with which are connected the only breathing-pores developed. For instance, the larva of the Drone-Fly (*Eristalis tenax*) is commonly known as the "rat-tailed maggot", on account of its possessing such a tube at the hinder end of the body (fig. 559). Special provision for a supply of air is particularly necessary in a form like this, for it lives in liquid filth, and so can only be called "aquatic" by courtesy.

The larvæ of the Common Gnat (*Culex pipiens*) are little red wriggling creatures, abundant in stagnant water. Each of them has a breathing-tube near the end of its tail, and every now and then comes to the surface for air, at which times the tip of the tube is pushed above the surface, and its valvular aperture opened. The valve is again closed when the larva has taken in sufficient air for the time being. Later on the quiescent pupa-stage in the life-history is reached, during which the creature floats at the top of the water, breathing now by means of a couple of tubes which project from the first ring of the thorax, the larval tube having disappeared. The pupa, however, is not so completely passive as the corresponding stage in a beetle or butterfly, for it is able to dive if necessary to escape any danger which threatens (fig. 560).

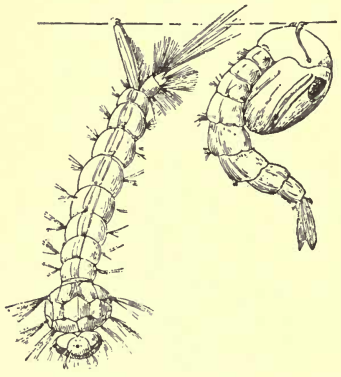


Fig. 560.—Larva (on left) and Pupa (on right) of Common Gnat (*Culex pipiens*), enlarged

SCORPIONS, SPIDERS, AND MITES (ARACHNIDA) AS AIR-BREATHERS

Upon the under side of the broad part of a Scorpion's abdomen four pairs of oblique slits are to be seen, opening into complex *lung-books*, which have been compared to plate-like appendages found in the corresponding region of a King-Crab. The air-containing cavity of each of these structures is largely filled by a considerable number of thin plates, which project inwards almost like the leaves of a book. The plates contain numerous blood-spaces, and collectively present a very large breathing-surface. It will be seen that the breathing organs are much more localized than those of the air-breathing arthropods already described, and

this necessitates a more complex blood-system, with better defined and more numerous vessels.

Whip-Scorpions possess two pairs of abdominal lung-books, similar to those of Scorpions. This is also the case with the larger Spiders, such as the bird-catching form (*Mygale avicularia*) of South America (fig. 561). The smaller species, such as the familiar Garden- and House-Spiders, present a modification of this arrangement. They retain the front pair of lung-books, but the hinder pair are replaced by two sets of air-tubes, resembling in character those of insects, though possibly of different origin.

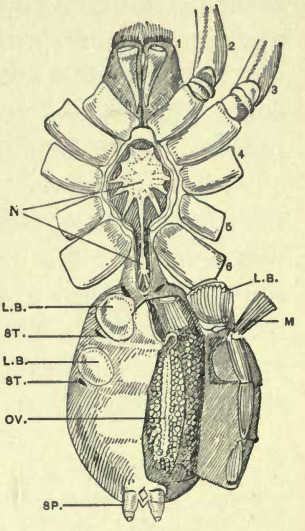


Fig. 561.—Mygale (partly dissected) from below

1, Cheliceræ; 2–6, pedipalps and walking-legs, cut short; L.B., lung-books, one of which is cut open to show leaflets; ST., openings into lung-books; M, a muscle-band; N., nervous system; OV., ovary; SP., spinneret.

The remaining groups of Arachnids possess air-tubes in those cases where special breathing organs are present at all. This is the case, for example, with many of the small forms known as Mites, of which Red "Spider" (*Tetranychus telarius*) is so provided. The Cheese-Mite (*Tyroiglyphus siro*) is an instance illustrating the absence of special breathing organs. In such cases respiration is effected by the general surface of the body, as in many small animals of widely different kind.

AIR-BREATHING CRUSTACEANS (CRUSTACEA)

We have seen that the lung-chamber of an ordinary land-snail (see p. 433) is really to be looked upon as a gill-cavity from which the gills have disappeared, and which has acquired a new way of breathing. Very much the same sort of statement can be made as regards the thorough-going Land-Crabs, creatures, no doubt, descended from ancestors which lived between tide-marks, and gradually came to depend less and less upon the air dissolved in sea-water. In such a land-crab the large gill-chamber has been converted into a lung, numerous folds and outgrowths being present on its lining, which offer a large surface for exposure to air. At the same time the gills have been very much reduced in size, and may even have practically disappeared.

The familiar land crustaceans known as Wood-Lice, common under stones and in the crevices of walls, present another instance of the same sort of thing. We here find that the limbs of the abdomen are used in breathing, and each of them consists in many cases of an outer and inner plate. The latter is delicate in texture, and does the respiratory work, while the outer plates are protective, and also prevent desiccation. The latter point is one of some importance, for it is probable that all sorts of wood-lice require damp air for breathing purposes. We have, in fact, a condition which is half-way between ordinary air-breathing and the state of things characteristic of thorough-going aquatic forms, which use the air dissolved in the water by which they are surrounded. It may also be added that in some kinds of Wood-Lice the outer plates of the abdominal limbs are hollowed out by air-cavities, especially in certain cases where the inner plates have altogether disappeared.

LAND NEMERTINES (NEMERTEA), EARTHWORMS AND LAND LEECHES (ANNELIDA), AND LAND PLANARIANS (TURBELLARIA) AS AIR-BREATHERS

None of the forms mentioned in the above heading possess special breathing organs, but respire by means of the skin, which is unable to perform its work unless kept moist. This is effected for the most part by means of a slimy substance secreted by the epidermis, just as in Frogs (see p. 423), which breathe partly in this way. It also follows that these various terrestrial forms can only live in damp places, being even more dependent upon a humid atmosphere than Wood-Lice (see above).

LAND NEMERTINES have been observed in widely separated parts of the world. One very interesting form (*Geonemertes Palaensis*) was discovered by Semper in so remote a locality as the Pelew Islands of the Pacific, where it lives among fallen leaves and the roots of trees.

EARTHWORMS.—When animals which possess a distinct blood-system breathe by means of the skin, that organ is always richly supplied with blood, an arrangement which is obviously favourable to absorption of oxygen and elimination of carbonic acid gas from the system. The Earthworms furnish a case in point, beside which the skin is not only of slimy nature, but there is also a

remarkable arrangement for keeping it moist and free from germs. The various organs of such worms are situated within a spacious cavity (body-cavity) containing a clear lymph-like fluid, and communicating with the exterior by means of a row of valvular pores placed on the middle line on the upper surface. Through these the fluid can be forced out from time to time, serving not only as a lubricant, but also, it would seem, as an antiseptic, checking the development of the numerous germs present in the surrounding earth, some of which might otherwise grow into injurious moulds, &c., upon the surface of the body.

Land Leeches, like almost all their aquatic relatives, breathe solely by means of the skin, the blood-supply of which penetrates even into the epidermis, a most unusual arrangement, but one which brings the blood very close to the surface, and promotes its rapid purification. This is probably correlated with the unpleasantly active habits of these creatures, regarding which Semper (in *Animal Life*) speaks as follows:—"We know . . . that there are a tolerably large number of true aquatic animals which constantly or occasionally live on land. To these, for instance, belong the true land leeches, as they are called, which live in the forests of India and the Indian islands, sometimes in such enormous numbers that it is quite impossible for men to exist in them even for a few hours. I myself have often been driven out of the woods of Luzon and Mindanao [in the Philippines], which are very favourable spots for insects and land-shells, by the myriads of leeches living on the trees and shrubs, from which they fall like a drop of dew on any human passer-by; and I once read that a whole English battalion had to beat a retreat during the Sikh rebellion because they were attacked in a wood by these small blood-suckers in such numbers that passing through the wood was not to be thought of. They dry up with particular facility; but as the air in these forests is constantly saturated with moisture, even in the driest season, they live in India in the open air on trees quite as well as their nearest allies, the medicinal leeches, do here in Europe in the water." This quotation also illustrates very well the easy transition between breathing in water and breathing in damp air which some groups of animals exhibit.

Land Planarians are members of a comparatively lowly group of Flat-Worms (Turbellaria) in which the body is not made up of rings or segments as in a Leech or Earthworm, and is there-

fore said to be *unsegmented.* The skin is also clothed with cilia, by means of which a gliding sort of locomotion is effected. Breathing is in all cases effected through the skin, and in the aquatic Planarians (which constitute the large majority of the group) the air dissolved in water is utilized for the purpose, while in the land-forms damp air is the breathing medium. We have in fact exactly the same sort of transition from one kind of breathing to the other as in the case of leeches. Land Planarians are found all over the world, especially in the tropical regions, where they attain a considerable size (as much as 18 inches in length) and are often brilliantly coloured. One such large form (*Bipalium Kewense*) has been accidentally imported in the earth surrounding the roots of tropical plants into Kew Gardens and many other places. In reference to the comparatively small and inconspicuous European species, Gamble remarks (in *The Cambridge Natural History*):—"In Europe there are only two or three indigenous Land Planarians, of which *Rhyncho desmus terrestris* is the most widely distributed, and has been found in moist situations for the most part wherever it has been looked for. It measures about ¾ inch in length, and is dark gray above, whitish below, and bears a pair of eyes near the anterior extremity." In regions which have alternate wet and dry seasons the Land Planarians tide over the latter, and protect themselves from being dried up, by burrowing into the ground and surrounding themselves with a sort of case made of hardened slime. A similar protective device has been noticed in regard to Earthworms, which during a dry summer may sometimes be found twined together in a sort of ball deep down in the ground.

CHAPTER XXXVIII

ANIMAL RESPIRATION—AMPHIBIOUS VERTEBRATES

The term "amphibious" is often applied to creatures like the Hippopotamus, which, though land-animals as regards structure, spend a large part of their time in the water. But, scientifically speaking, this is on a par with the well-known definition of an Amphibian as "an animal which cannot live on land and dies in the water", which utterance is supposed to have been derived from a perennial source of oracular knowledge, *i.e.* the answers to examination papers. Zoologists apply the term *amphibious* to animals which throughout life are able to breathe both air dissolved in water and ordinary air, or which carry on the former mode of respiration during the earlier part of their existence, becoming air-breathers in the limited sense when adult.

So far as backboned animals are concerned, it is convenient to consider Amphibious Fishes in the first place, and then to deal with Amphibians proper, such as newts, frogs, and their kindred.

AMPHIBIOUS FISHES (Pisces)

There can be no doubt that land-vertebrates are descended from aquatic ones, and since these last are typically represented at the present day by fishes, it is among such animals that we must look for transitional forms which help to bridge the gap between the inhabitants of the water and the dwellers on land.

Among Ordinary Bony Fishes (Teleostei) there are a number of species which, though not properly speaking amphibious, are very tenacious of life, and can exist for some time on land, if surrounded by a damp atmosphere. It is among freshwater fishes that this kind of peculiarity is best marked, and the Common Eel (*Anguilla vulgaris*) is the most familiar instance. This

creature is able to make its way through damp herbage for considerable distances, the object apparently being migration from one pond or river to another. In correlation with this habit the external breathing aperture is narrowed somewhat as in a mud-skipper (see below), though most likely this character was first acquired to hinder mud from making its way into the gill-cavity and blocking up the gills.

Carp and their allies are often extremely tenacious of life, some of them being able to thrive in stagnant water, and others to endure exposure to the air for a considerable time, provided it be not too dry. Regarding the Common Carp (*Cyprinus carpio*), Günther remarks (in *The Study of Fishes*):—"They can also be preserved alive for a considerable length of time out of the water, especially if care be taken to moisten them occasionally as they become dry. Advantage is often taken of this circumstance to transport them alive, by packing them among damp herbage or damp linen; and the operation is said to be unattended with any risk to the animal, especially if the precaution be taken to put a piece of bread in its mouth steeped in brandy!" The Tench (*Tinca vulgaris*) can live in stagnant water of so foul a nature as to be fatal to most other fishes, which suggests that it probably makes up for the deficiency of oxygen by rising to the surface to take in air.

Cases like those just described lead on to others where the term amphibious is correctly applied. The most striking marine forms of this kind are the little Mud-Skippers (*Periophthalmus*), which hunt for small crustaceans and the like between tide-marks on the shores of the Indo-Pacific (see p. 87). To prevent the gills from drying up at such times the external opening behind the gill-cover is not a wide slit as in, say, a herring or perch, but has been reduced to a comparatively small hole. It also appears that the gill-cavity is relatively spacious, and most probably its lining performs the functions of a lung. Another very interesting fact concerning the breathing of these fishes is thus described by Hickson (in *A Naturalist in Celebes*):—"Their position is usually one of clinging to the edge of the rocks or mangrove roots by their fins, with their tails only in the water. . . . The fact that they live the greater part of their lives with their head and gills out of water suggested to me an investigation of their respiratory organs, as I thought it possible that they

THE MUD-SKIPPER (PERIOPHTHALMUS KOELREUTERI)

A STUDY BY M. A. KOEKKOEK

UNIV. OF
CALIFORNIA

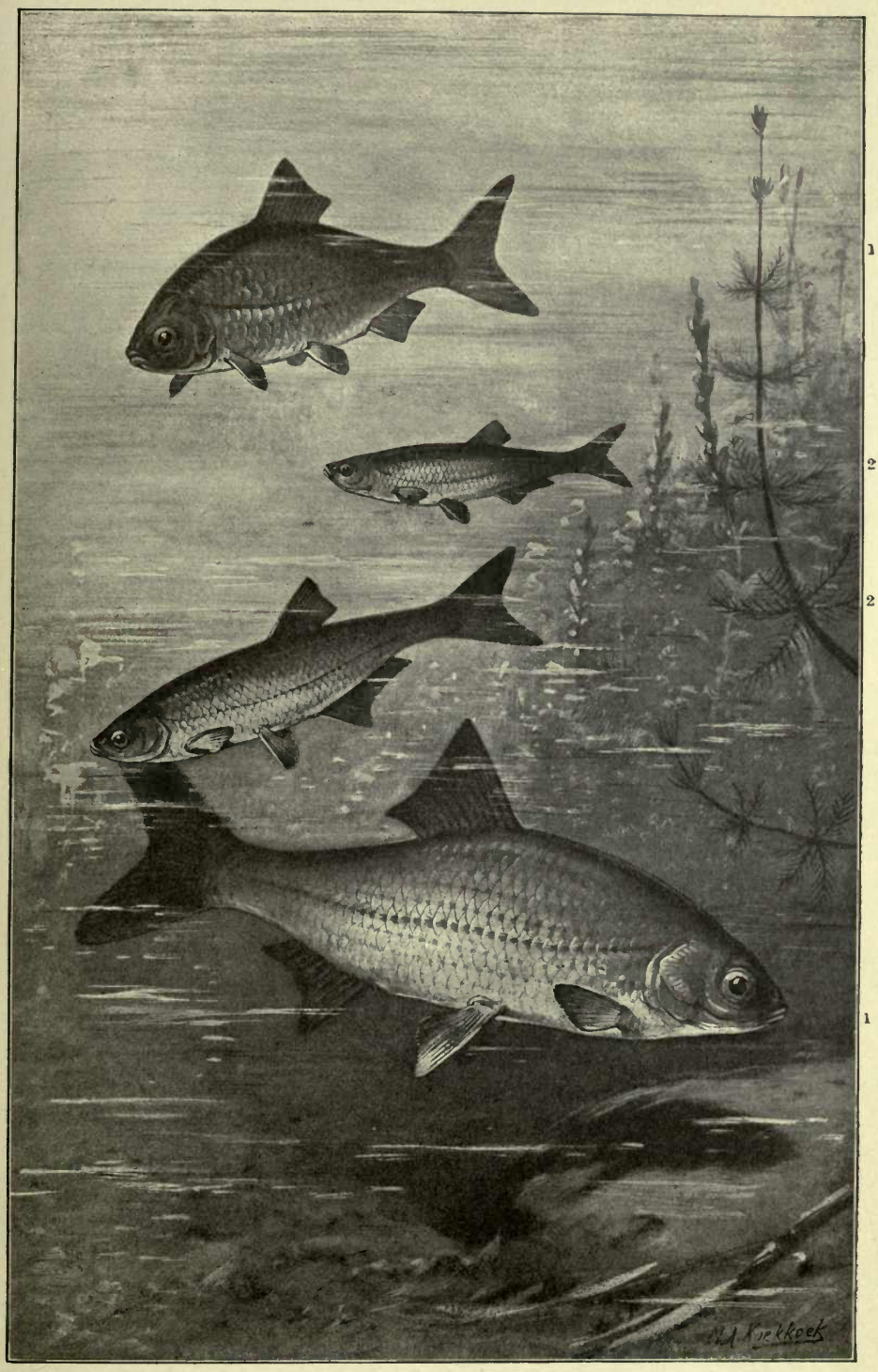


Fig. 562.—1, Roach (*Leuciscus rutilus*) and 2, Bleak (*Alburnus lucidus*)

might possess some interesting modifications of the swim-bladder to enable them to breathe the air. It was not, however, until . . . 1887 that an explanation of the mystery of their respiration occurred to me—namely, that the respiration is mainly performed by the tail. Since then Professor Haddon has been carrying on some experiments in Torres Straits, and has shown that this explanation is correct. It seems at first sight a very extraordinary thing that a fish should have become so modified by change of habit as actually to have transferred the chief part of its respiratory functions from its gills to its tail. It is a well-known and generally recognized fact, however, that in all the Amphibia the skin plays a very important part as an organ of respiration, and it is quite possible that the thin skin between the fin-rays of many fishes also acts as an accessory to the gills and performs the same function. If this is proved to be the case we should have to look upon the tail of Periophthalmus as an example of an organ discharging a function which is performed in a lesser degree by the tails of many if not of all fishes."

Among freshwater forms some of the carp-like fishes, such as the Bleak (*Alburnus lucidus*) and Roach (*Leuciscus rutilus*) (fig. 562), are definitely known to rise from time to time to the surface in order to swallow air, since the oxygen dissolved in the surrounding water is not sufficient for their breathing processes. It therefore follows that such forms, extraordinary though the statement may seem, can be drowned by keeping them below the surface. Definite experiments have been made which prove this. For example, Semper (in *Animal Life*) makes the following statement:—"If we prevent the species of *Leuciscus* [*i.e.* Roaches, &c.] from coming to the surface of an aquarium by placing a wire net just below the surface of the water, so that they cannot gulp the air, they soon die, even when an ample supply of highly aerated water is constantly added". It is suggested that part of this air is breathed by the lining of the digestive tube, and this is definitely known to be the case in the small freshwater fishes called Loaches, which also are in the habit of swallowing air. Two species of Loach are native to Britain, the Common Loach (*Nemachilus barbatulus*) and the Spiny Loach (*Cobitis tenæa*). But all these freshwater forms quickly die when taken out of the water.

It is, however, by tropical freshwater fishes that a double

mode of breathing is most frequently exemplified. This is partly related to the fact that in the dry season the smaller streams of such regions are liable to great reduction in size, and the habit is also favoured by the great moistness of the air during the wet season. The Snake-headed Fish (*Ophiocephalus*) of India, for instance (fig. 563), possesses what is generally termed an

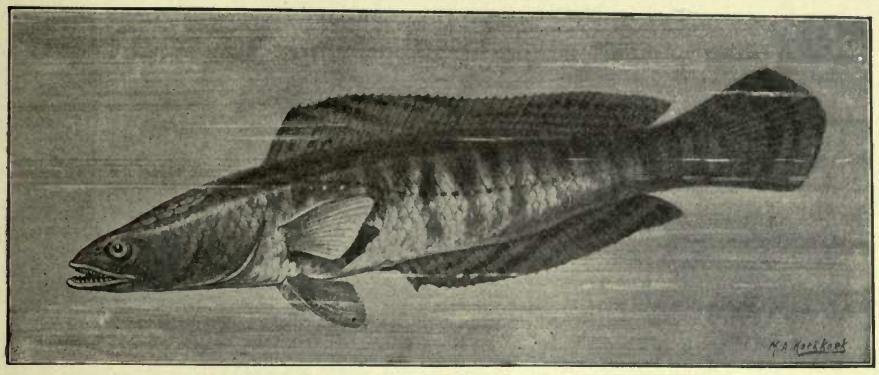


Fig. 563.—Indian Snake-headed Fish (*Ophiocephalus*)

accessory gill-cavity covered by the upper part of the gill-cover, but this cavity does not contain any gill-folds and is probably to be looked upon as constituting a sort of lung. The habits of these forms are described by Günther (in *The Study of Fishes*) in the following words:—"Like other tropical freshwater fishes, they are able to survive drought, living in semi-fluid mud, or lying in a torpid state below the hard-baked crusts of the bottom of a tank from which every drop of water has disappeared. Respiration is probably entirely suspended during the state of torpidity, but whilst the mud is still soft enough to allow them to come to the surface, they rise at intervals to take in a quantity of air, by means of which their blood is oxygenized. This habit has been observed in some species to continue also to the period of the year in which the fish lives in normal water, and individuals which are kept in a basin and prevented from coming to the surface and renewing the air for respiratory purposes are suffocated." The same kind of specialization is carried still further in the Climbing Perch (*Anabas scandens*), where the cavity above the gills has its lining raised into a number of folds, by which the breathing surface is largely increased (fig. 564). This fish is known to come out of the water and undertake comparatively

lengthy excursions on land, while it is even accredited with the power of climbing trees, and has been named in accordance with this belief.

The arrangements described for the last two sorts of fish, though extremely interesting, do not form a stage in the evolution of the backboned animals which live on land. And we now proceed to the consideration of those fishes which do throw

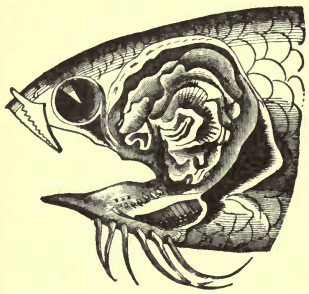


Fig. 564.—Climbing Perch (*Anabas scandens*). Side of head dissected to show accessory breathing organs.

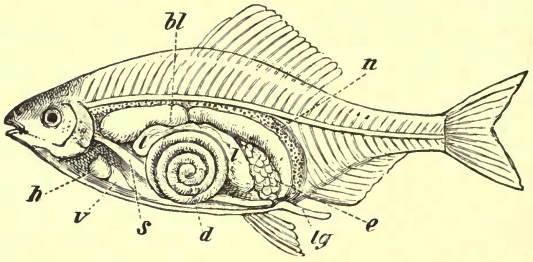


Fig. 565.—Dissection of a Bitterling (*Rhodeus amarus*)

bl, Swim-bladder narrowed in the middle; *s*, gullet; *d*, intestine; *ll* liver; *v* and *h*, auricle and ventricle of heart; *n*, kidney; *e*, ovary; *lg*, egg-laying tube (rarely present in fishes).

some light on the way in which such forms have originated from aquatic ancestors.

Evolution of the Lungs of Backboned Animals.—It has already been pointed out (see p. 421) that the lungs of a Frog, Lizard, or other air-breathing land-vertebrate are comparable to the *swim-bladder* possessed by many fishes, serving in them to buoy up the body and helping to maintain its equilibrium (fig. 565). The swim-bladder is developed as an outgrowth from the front part of the digestive tube, with which it often remains connected throughout life by means of a *pneumatic duct*. It contains a mixture of nitrogen and oxygen, the latter gas being more abundantly present in freshwater species. In some of the Ordinary Bony Fishes (Teleosts) it has been shown that air is actually taken into this organ from the exterior, and that this furnishes what may be called a new method of breathing, supplemental to that of the gills. Indeed it has been proved in some such cases that the gills alone cannot do all the necessary work of respiration. For instance, it has been found that in some of the freshwater fishes of tropical South America (species of *Erythrinus*) suffocation quickly takes place if air be prevented from entering the swim-bladder.

Among recent Ganoid Fishes the Gar-Pike (*Lepidosteus*) and Bowfin (*Amia*), which live in the fresh waters of North America, both possess a swim-bladder which is better adapted to act as a lung than is the case in forms so far considered, since its lining is raised into complex folds which give a large surface through which exchange of gases can go on. The Bowfin has been observed to come from time to time to the surface for the purpose of swallowing air. The swim-bladders so far described are unpaired structures which grow out from the side or upper surface of the gullet, facts which have been cited as opposed to the view that lungs have evolved from organs of the sort, for lungs are paired and grow from the under side of the gullet. The first point is of little importance, for the lungs are represented by an unpaired outgrowth when they first appear, this later on dividing into two branches. It may be noted here that both in the Gar-Pike and Bowfin the air-bladder is narrow in the middle and broad at the sides, giving a sort of incipient doubleness. Neither objection applies when we come to examine the air-bladders of the archaic African ganoids, the Bichir (*Polypterus*) and Reed-Fish (*Calamoichthys*), for in both of them the swim-bladder is double, and grows out from the under side of the gullet. The lining of this organ being smooth in these fishes, the breathing work done by it is probably less in amount than in the two ganoids first mentioned. It is worth while noting that Bichir and Reed-Fish belong to a distinct and much more ancient group than other living forms to which the term ganoid is commonly applied. Fishes of similar kind were exceedingly abundant in some of the older geological periods. It is hence extremely probable that in the first instance the swim-bladder of fish-like forms grew out from the under side of the gullet, but in most cases its point of origin has gradually shifted round to the upper side as a matter of convenience, since this organ is usually placed immediately below the backbone (and above the digestive tube), a position most suitable for the proper performance of its duties in regard to the maintenance of equilibrium.

Lung-Fishes (Dipnoi).—The contention that lungs have evolved from swim-bladders receives its strongest support from the structure and habits of the remarkable Lung-Fishes, of which the three existing forms, native to the rivers of Australia, Africa, and South America, are the last survivors of an exceedingly an-

cient and once extensive group. They are admittedly amphibious, and have received both their popular and scientific names (Gk. *dis*, double; *pnoē*, breath) in acknowledgment of the fact. So much do they differ from other fishes in structure that some zoologists place them in a separate class, and, since in many respects they resemble newts, salamanders, and the like, they may broadly be considered as a sort of half-way stage between Fishes proper and Amphibians.

The Australian Lung-Fish (*Ceratodus*) is the least specialized of the three living representatives of its group, and its lung-like swim-bladder is unpaired (but divided by furrows into right and left parts), though it grows out from the under side of the gullet. The lining of this organ is raised into folds, and it returns purified blood to the heart, which we find in consequence to be partly divided into right and left divisions by a partition, so as to keep apart in some degree the two kinds of blood which are poured into it. It is, in fact, the first crude attempt at solving the problem of converting a fish-like type of heart, which receives only impure blood and pumps it to gills for purification, into the kind of heart found in typical air-breathing Vertebrates, which receives both pure and impure blood, that are only disposed of to the best advantage when kept separate (see vol. i, pp. 242–244). It is only the two highest classes of backboned animals, *i.e.* Birds and Mammals, that have attained to a full solution of the problem, and have succeeded in keeping the two sorts of blood completely separate. That the members of these two classes are hot-blooded is one outcome of this feat, and to it they owe, in no small degree, their present position as the dominant inhabitants of the land. For long ages Reptiles were the leading terrestrial forms, but never completely succeeding in converting circulatory organs inherited from aquatic ancestors into structures thoroughly adapted to air-breathing, ultimately had to give place to Birds and Mammals, in which the course of evolution led to more satisfactory results in this and certain other respects.

Returning from this digression to Ceratodus, it is to be noted that this creature is only found in a remarkably restricted area, being limited, in fact, to two small Queensland rivers, the Burnett and Mary, each of which is practically a chain of deep water-holes, connected by comparatively shallow reaches. Fossil evidence proves that the area of distribution was once very much

more extensive. There is abundant testimony showing that this fish actually does breathe air. For example, Semon, who has recently studied the habits of Ceratodus in its native rivers, writes as follows on this point (in *In the Australian Bush*):—"As aforesaid, Ceratodus is a representative of the almost exterminated class of Dipnoi or lung-fish; that is to say, fish possessing gills by which they breathe like other fish, but also an air-bladder, the construction and function of which very much resembles that of a lung. What does Ceratodus use this lung for, since it does not go on land, and therefore is not forced to adapt itself to extra-aquatic conditions of breathing and living. . . .? That the fish uses its lung for breathing I noticed hundreds of times. Near the river area it haunts one occasionally hears a dull groaning sound. This is produced by the fish, which comes up to the surface at certain intervals to empty the breath from its air-bladder and to take in fresh air. I readily proved Ceratodus to be the author of this strange noise when later on I kept the fish alive in great barrels and self-dug water-holes. I then saw them appear at the surface every thirty or forty minutes and lift the tip of their snout above the water, at the same time uttering the afore-mentioned grunting noise. Still I was unable to make out whether it is produced by the expiration of the foul air or the inspiration of the fresh, and how or where it originates." The author then goes on to explain how the possession of a lung is related to the actual conditions of life: "At the same time, like any other fish, Ceratodus makes use of its gills, and is by no means able to exist on land. If taken out of the water and prevented from getting back, its gills soon dry up and the animal dies. Nevertheless its lungs are of great importance to the fish during the dry season, for when the water evaporates over a wide area and the river gets reduced to some few water-holes, the dimensions of which naturally decrease from day to day, an immense accumulation of river inmates takes place within these last havens of refuge. The water thus rapidly becomes foul and putrid by rotting animal and vegetable substance, and the fishes die in numbers. Mr. W. B. Maltby of Gayndah told me that he had once emptied a big but not very deep water-hole, which was approaching dryness. The little water at its bottom was filled with dead mullets, perches, and other fishes, and the whole was putrid with fish corpses. Some Ceratodus, however, which were contained in this pool were

perfectly lively and at their ease, and not in the least disturbed by finding themselves among these most unsanitary surroundings. This is the occasion when Ceratodus enjoys the advantage of its lungs. Not on land, not during a summer sleep in the mire or in a cocoon are they most serviceable, but in an extremity of this kind, when they furnish the only means by which the fish manages to outlive the most unfavourable conditions of its native rivers."

The African Lung-Fish (*Protopterus*), specially abundant in the basins of the White Nile and Congo, is more specialized than its Australian congener, and its swim-bladder is modified into a double lung with spongy wall. It is commonly found living in swamps or shallow streams which practically disappear during the dry season, and spends that part of the year in a torpid condition (summer sleep), imbedded in the mud, and surrounded by a sort of capsule or cocoon formed by the hardening of slime secreted by its skin. In this state, it is said, the natives dig it out for food, and dormant specimens of the kind have been transported to Europe, surrounded by the capsule and a mass of hardened clay. When placed in warm water these investments readily break down, and the fishes thus released are none the worse for their long journey. The newly-hatched Mud-Fish possesses not only internal gills, but also long, plume-like *external gills* (like those of a tadpole), which persist in the adult, though in a reduced state.

The American Lung-Fish (*Lepidosiren*), native to the basins of the Amazons and Paraguay Rivers, closely resembles the African form in the structure of its breathing organs and in its habits. Prof. Graham Kerr has shown that, during the egg-laying season, numerous scarlet filaments grow out from the pelvic fins of the male in a feather-like way, and he considers these to be accessory breathing organs.

AMPHIBIANS (Amphibia)

Certain Tailed Amphibians (*Urodela*) are amphibious in the adult condition, possessing a pair of simple lungs, and also gills. This is the case with some of the Salamanders, creatures which may be regarded as first cousins of the Newts or Efts which abound in many of our ponds and ditches. In the Hell-Bender

(*Cryptobranchus lateralis*) of the Mississippi, the gills are said to be "internal", being in the form of folds on the walls of gill-pouches, much like those of many fishes, and a gill-opening is present on the left side of the neck. These gills are evidently on the down-grade, and are still further reduced in the Giant Salamander (*Megalobranchus maximus*) of Japan and China, where the gill-pouches are fewer in number and there is no external gill-aperture.

A few adult Amphibia supplement their lungs by tufted *external gills* growing out from the sides of the neck. One of these forms is the Olm (*Proteus anguineus*), found in the underground waters of Carniola. In shape it resembles an eel, but possesses small fore- and hind-legs. A somewhat similar form, the Siren Salamander (*Siren lacertina*), inhabits the pools of swampy districts in the south-east of the United States. In this species the hind-legs have disappeared altogether.

The large majority of adult Amphibians, such as ordinary Salamanders, Newts, Toads, and Frogs, breathe only by means of lungs (and skin) in the adult condition. Like all other Amphibia, however, they begin life as fish-like tadpoles, which possess gills, and are at first devoid of limbs. If they did not develop beyond this stage they would undoubtedly be classified as fishes. This remarkable life-history is the most remarkable characteristic of Amphibians, to which, indeed, their name has reference (Gk. *amphi*, both; *bios*, life). Just as the Lung-Fishes bridge the gap between ordinary Fishes and Amphibia, and demonstrate how lungs have been evolved from swim-bladders, so do the Amphibians lead up to the thorough-going land-groups of Reptiles, Birds, and Mammals, which at no period of life possess gills, although in the early stages of their existence gill-arches and gill-clefts remain as a testimony to their aquatic ancestry.

If we follow the development of a common Grass Frog (*Rana temporaria*) we shall find that the young tadpole breathes by three pairs of plume-like *external gills*, much like those present in the adult Olm and Siren. Later on these are replaced by "*internal*" *gills*, in the forms of folds on the outer sides of the gill-arches. These are not strictly comparable to the gills of ordinary fishes, but serve the same purpose. After a time a fold of skin grows back over the gills, leaving only an opening to the exterior on the left side of the body, and ultimately these organs gradually

shrivel up and the gill-clefts close, while at the same time the lungs grow out from the under side of the gullet. Corresponding changes take place in the heart and blood-vessels, and, as often remarked, the successive stages in the life-history afford a practical lesson in evolution; for if such a startling series of changes can take place in the life of one animal, it is not difficult to picture a similar sequence of events in the evolution of a group.

CHAPTER XXXIX

ANIMAL RESPIRATION—AMPHIBIOUS INVERTEBRATES

As will already have been gathered from what has been said in chapter xxxvii, numerous interesting illustrations of the amphibious habit are furnished by certain members of the important animal groups of the Mollusca and Arthropoda.

MOLLUSCS (Mollusca)

Origin of Land-Snails and Slugs.—We have seen in the last chapter how the study of amphibious fishes throws light upon the evolution of land vertebrates, and amphibious species are included in typical groups of both marine and freshwater molluscs, which enable us to understand how land-snails proper have originated from aquatic ancestors. It is extremely probable that land molluscs have been derived from two sources, some being descendants of marine forms living between tide-marks, and others offshoots from estuarine or freshwater groups. In the latter case we are obliged to fall back in the end upon the sea as the original home of molluscs, for from it have been populated the estuaries and rivers of the globe. And, as in the case of land vertebrates, aquatic molluscs have given rise to land molluscs as the result of a keen struggle for existence, which has driven certain forms of life from sea to land, either directly or after a more or less prolonged sojourn in brackish or fresh water.

Among the most interesting marine snails which afford a hint as to one set of conditions under which amphibious habits may be acquired are the species included in the Periwinkle Family (*Littorinidæ*), plant-eating forms characteristic of the region between tide-marks. The gill-cavity is here more or less adapted for breathing damp air when the tide is down, and the contained gill is reduced in size, as its chief work is done when the animal

is covered by water. In the case of those kinds of Periwinkle which live high up on the shore we should naturally expect to find the gill more reduced than in allied species living further down, since in the former case its work would be inconsiderable, as its owner would only be covered with water for a brief period of time. Such an expectation is actually realized in one British species (*Littorina rudis*) which lives near high-water mark, and which has a smaller gill than the common kind (*L. littorea*) that spends a larger part of its life under water. In the former species, too, folds richly supplied with blood-vessels are beginning to appear on the inner surface of the gill-cavity (fig. 566), so as to increase its efficiency as a lung. After what has been said it will not surprise the reader to hear that there are certain tropical forms of Periwinkle (native to Central America and the West Indies) which live to a considerable extent above high-water mark, and are even found upon trees. Such cases lead on to certain families of Snails living on land, in which the gill has entirely disappeared, but which otherwise are probably closely related to Periwinkles. These families are among those known as Land Operculates, on account of the possession of an *operculum* or plate by which the aperture of the shell is closed when the animal is completely withdrawn into it. It must not be supposed, however, that all the families of land operculates are related to Periwinkles, for some of them can be shown with considerable probability to be allies of other sorts of marine Snails.

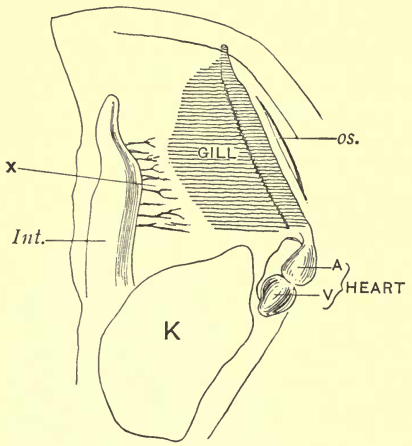


Fig. 566.—Roof of Gill-cavity in a species of Periwinkle (*Litterina rudis*), which lives near high-water mark (enlarged). Front end is at top of figure. X, Commencing net-work of lung-folds; *Int.*, intestine; A and V, auricle and ventricle of heart; K, kidney; *os.*, water-testing organ (osphradium).

It is quite possible that some kinds of snail which are now adapted for a life on land, and breathe by gill-cavities which simply serve as lungs, may have been derived from amphibious *freshwater* ancestors. We know at any rate that double-breathers of the kind actually exist, the most striking case being that of the Apple-Snail (*Ampullaria*), native to both Africa and South

America (fig. 567). The gill-cavity is here divided into upper and lower parts by an imperfect partition, and a long breathing-tube (*siphon*) can be protruded from the left side of the neck. The upper part acts as a lung, and its lining is raised into numerous folds so as to increase the air-breathing surface, while the lower part contains a gill on the right side. Semper (in *Animal Life*) thus describes the way in which the two divisions of the breathing apparatus are used:—"The Ampullaria uses both organs in rapid alternation; lying not far from the surface of the water, it protrudes above it a breathing siphon, and inhales air through it; then it closes its lungs, reopens the siphon, and admits a stream of water through it into the branchial cavity". We are here strongly reminded of certain freshwater fishes already described (see p. 450), which frequently come to the surface to take air for breathing into their swim-bladders.

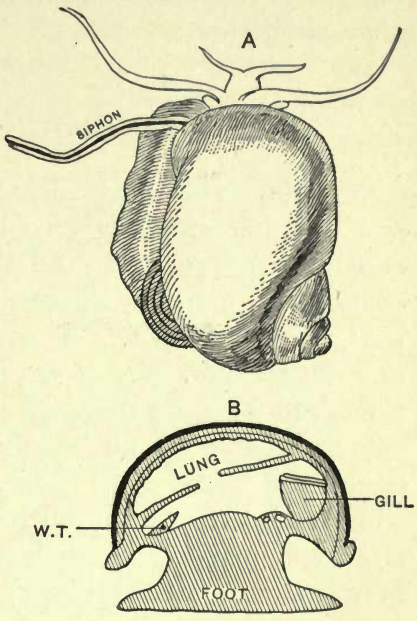


Fig. 567.—Apple-Snail (*Ampullaria*)

A, Upper surface; B, vertical section across breathing-organs (diagrammatic); W.T., water-testing organ

We have so far dealt with the origin of only operculate land-snails, many of which are closely related to Periwinkles and other sea-snails belonging to the Fore-gilled (Prosobranch) marine forms (see vol. i, p. 318). Such terrestrial molluscs, though common enough in tropical regions, are quite different from the ordinary land-snails and slugs with which we are familiar in this country, and which constitute the group of Lung-Snails and Slugs (Pulmonates), which do not possess an operculum to close the mouth of the shell, and may even have no shell at all. Some at least of these have probably been derived from the marine forms known as Hind-gilled Snails and Slugs (Opisthobranchs), exemplified by Bubble-Shells, Sea-Hares, Sea-Slugs, and many others (see vol. i, p. 324). The chief evidence in support of this view consists in the existence of a family of shore-snails (*Siphonariadæ*)

which are shown by their structure to be half-way between hind-gilled snails and lung-snails. In one member of the family (*Siphonaria*) the gill-cavity is partly converted into a lung and the gill is reduced, while in an allied form (*Gadinia*) the gill has gone altogether.

AMPHIBIOUS INSECTS (Insecta)

Certain cases have already been described of insects which live in water either when adult or during early stages of existence (see p. 439). But all the aquatic forms of the kind so far dealt with are strictly air-breathers, either carrying about a supply with them under water, or coming up to the surface from time to time for the purposes of respiration. There are, however, insects which are far more thorough-going water animals than this, being able to breathe the air dissolved in water during the early part of their lives. And since such forms are typical air-breathers when adult, they are just as much entitled to be called amphibious as frogs and newts. There is, nevertheless, a very great difference between the ancestral history of amphibious vertebrates and amphibious insects. The former are terrestrial forms emerging, as it were, from the aquatic mode of life, and dependent upon a damp atmosphere even when adult. Amphibious insects, on the other hand, are members of a group which is thoroughly terrestrial, and, like birds, has even conquered the realms of air. There can be no doubt that in the very remote past insects sprang from aquatic ancestors, but there is no reason to suppose that these were in the least like the water-inhabiting stages of such members of the class as are amphibious. It is, in fact, a case of the re-acquirement of aquatic habits in the history of a group, *i.e.* it is a *secondary* phenomenon, while the amphibiousness of frogs and the like is a *primary* phenomenon, due to the fact that they have been specialized from fish-like creatures, which are recapitulated, as it were, by the tadpole stage.

Amphibious insects chiefly, if not entirely, belong to one or other of two orders, Net-winged Insects (*Neuroptera*) and Two-winged Insects (*Diptera*), which it will be most convenient to consider separately.

AMPHIBIOUS NET-WINGED INSECTS (NEUROPTERA)

The most remarkable structures by which amphibious insects are enabled to breathe the air dissolved in water are those known as *tracheal gills*, which may be briefly defined as gills traversed by air-tubes (*tracheæ*) that do not open to the exterior. Gills of this sort are found in the early stages of many net-winged insects, but are rare in the adults. They are clearly of secondary nature, *i.e.* do not correspond to the gills of an ancient ancestral stock, for the air-tubes which they contain are structures evolved with reference to air-breathing (see p. 434), and are here pressed into the service, as it were, of breathing in water. The gill itself is an outgrowth of the body which offers a large surface for exchange of gases between the air in the air-tubes and that dissolved in the surrounding water. The evolution of an aquatic mode of life requires a very long time, especially when it takes place in so typical a class of land animals as insects, and even without definite evidence it would be reasonable to suppose that the amphibiousness of certain insects has taken longer to come about than the acquirement of an aquatic habit by the insects, elsewhere described, which are not able to breathe air dissolved in water. There is, however, positive geological evidence to show that the tracheal gills of net-winged insects are structures of very great antiquity. Numerous fossils belonging to this group have been found in rocks belonging to that immensely remote period to which the name Carboniferous has been applied because its luxuriant vegetation has been converted into those coal-deposits which are of greatest importance. Many of the extinct insects of that period belong to existing groups of Net-Wings, while others, though referable to this order, constitute groups which have no living representatives. One of these insects (*Corydaloides Scudderi*) is especially interesting, for, when adult, it possessed tracheal gills resembling those found in the early stages of May-Flies, such as will be described later on.

We will now consider the amphibious members of certain families of Net-winged Insects. These are: Stone-Flies (Perlidæ), Dragon-Flies (Odonata), May-Flies (Ephemeridæ), Alder-Flies (Sialidæ), and Caddis-Flies (Phryganeidæ).

Stone-Flies (*Perlidæ*).—These insects, of which about two dozen British species are known, live in rapidly-flowing streams

during the early part of their existence, and, although land-animals when adult, are always found in the neighbourhood of water. There is no quiescent or pupa stage in the life-history, but the young Stone-Fly, when hatched from the egg, closely resembles the adult, except that wings are absent. It is usual to apply the term *nymph* to a stage of this sort, reserving the word *larva* for caterpillars, grubs, and the like, that are very unlike the perfect insects which they become after passing through a more or less quiescent pupal condition.

The nymphs of Stone-Flies possess numerous air-tubes, but these do not open to the exterior by means of spiracles. Breathing is either effected through the skin, which is very thin at certain spots, or by means of tracheal gills, which differ in shape and position. These gills persist in the adult (as, *e.g.* in *Pteronarcys*), though they often become reduced in size, and it is not known how far they are of any use (fig. 568). That they should persist at all is very interesting in view of the fact that in certain extinct forms (see p. 463) they were possessed by the perfect insect. We know that the coal-plants, among which these ancient insects lived, grew in jungles and swamps where the air was very damp, and this probably favoured the retention of tracheal gills throughout life.

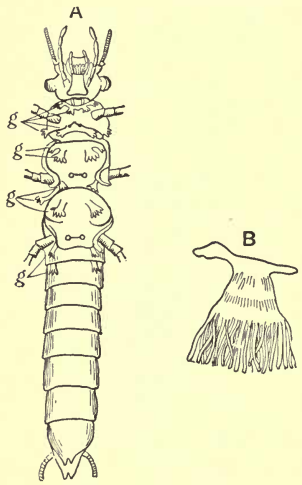


Fig. 568.—A Stone-Fly (*Pteronarcys*)
A, Under side of adult, with limbs cut short; *gggg*, reduced tracheal gill-tufts (enlarged); B, a gill-tuft (more highly magnified).

Dragon-Flies (*Odonata*).—A female dragon-fly lays her eggs either in the water or upon the stem of a water-plant, and they hatch out into flattened wingless nymphs, which possess an elaborate system of air-tubes that probably do not communicate with the exterior. The way in which such nymphs breathe is not always the same, but the commonest, and at the same time the most interesting, is by means of *rectal gills*, so called because they are folds in the lining of the last part of the intestine (*rectum*). These folds are either plate-like or in the form of small finger-shaped projections, but in either case they are richly provided with air-tubes, and collectively possess a very large breathing surface (fig. 569). The rectum alternately contracts

and dilates, so that water is forced out and drawn in rhythmically. When the nymph develops into the adult dragon-fly, spiracles are acquired by the system of air-tubes, the water is abandoned, and ordinary air is breathed in the manner usual among insects.

May-Flies (*Ephemeridæ*).—The adult insects are here thoroughly aerial, as in the groups of Net-Wings so far described, but the nymphs present a maximum amount of adaptation to an aquatic mode of life. They possess tracheal gills of various kind, a typical case being that of the Common May-Fly (*Ephemera vulgata*), in which these structures are in the form of a double series of tufted outgrowths running along the abdomen, and traversed by numerous air-tubes (fig. 570). Breathing is also helped, it would appear, by three feathery rods which project from the hinder end of the body, and which differ greatly both in structure and mode of action from tracheal gills. The arrangement has been worked out in detail in the nymph of one kind of May-Fly (*Cloëon dipterum*). As in Insects generally, the heart is here a slender tube situated in the middle line close below the upper surface of the body. It consists of a series of chambers which receive blood by means of paired valvular apertures and pump it forwards. To this direction of blood-flow there

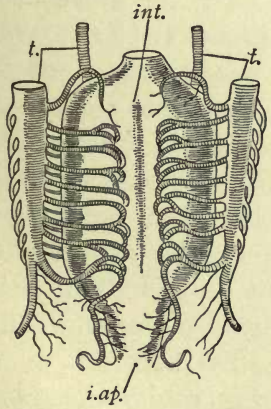


Fig. 569.—Dragon-Fly Nymph

Dissection to show air-tubes (*t.t*) which supply rectal gills; *int.*, intestine (rectum); *i.ap.*, intestinal aperture. Enlarged.

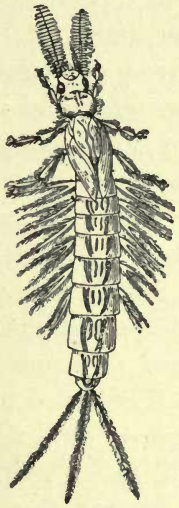


Fig. 570.—Nymph of Common May-Fly (*Ephemera vulgata*), enlarged, to show tracheal gills at sides and three tail-rods.

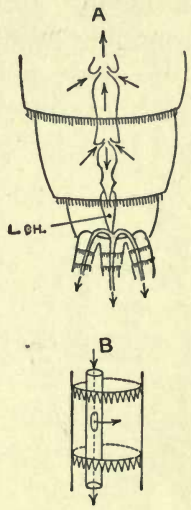


Fig. 571.—Hinder part of Nymph of a May-Fly (*Cloëon dipterum*), enlarged. A, Last three segments and bases of tail-rods. Last chamber (L.CH.) of heart gives off vessels to the tail-rods. Arrows indicate direction of blood-flow. B, Part of a tail-rod, showing perforated walls of central blood-vessel.

is, however, one exception in this particular case, for part of the blood from the last chamber but one passes back through a pair of valves into the last chamber, which forces it into the three tail-rods through a corresponding number of vessels (fig. 571). Each of these vessels is perforated by a series of oval holes through which the blood escapes into the rods, which are hollow, and it is then returned to the body, presumably in a purified condition, having absorbed some of the dissolved oxygen from the surrounding water and got rid of waste carbonic acid gas.

We have noted in a previous chapter that the delicate gills of such creatures as fishes and the higher crustaceans are protected by being placed in special gill-cavities. Tracheal gills may also be sheltered in various ways. They sometimes grow out from the under sides of firm plates (*Oligoneuria*), and in other cases the gills of either side are shielded by a flat gill-cover (*Tricorythus*). But the most remarkable instance is afforded by the nymphs of certain May-Flies (species of *Prosopistoma*) which are native to Europe, West Africa, and Madagascar. The nymph, which lives in swift streamlets, looks like, and was formerly mistaken for, one of the lower crustaceans (fig. 572). The head and front part of the abdomen are covered by a sort of shield, under which there is a gill-cavity containing five pairs of tracheal gills. Water flows into the cavity through an opening on either side, and out again by a single aperture at the back. Sharp (to whose admirable volumes on Insects in *The Cambridge Natural History* the present writer is here and elsewhere greatly indebted) says of this nymph that it is "more completely adapted for an aquatic life than any other insect at present known".

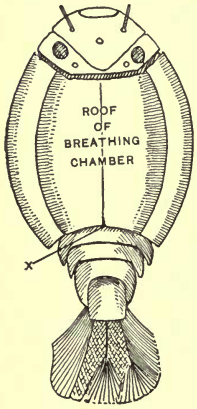


Fig. 572.—Crustacean-like Nymph of a May-Fly (*Prosopistoma*), enlarged. X, Opening of breathing-chamber.

It only remains to mention that the nymphs of some May-Flies appear to partly breathe by means of the rectum, like the corresponding stages of Dragon-Flies which have been already described.

Alder-Flies (*Sialidæ*).—The Alder-Fly (*Sialis lutaria*) is a very common British insect which haunts the banks of sluggish streams. The eggs are laid in regular rows on rushes or other plants which grow near the water. The aquatic young which

hatch out from them may be called larvæ (not nymphs), because they differ considerably from the adult, into which they do not pass directly, there being an intermediate quiescent or pupa stage. Each of the first seven rings of the abdomen bears a pair of tracheal gills in the form of jointed threads, and an unjointed rod projects backwards from the tip of the tail. The gills are kept in constant motion, so that the water in their vicinity is continually renewed.

Caddis-Flies (*Phryganeidæ*).—An adult Caddis-Fly has four somewhat hairy wings, giving it some resemblance to a moth; indeed, it is sometimes called a Caddis-"Moth". The eggs are laid in water, and from them elongated larvæ hatch out, which are familiarly known as "caddis-worms", and construct for themselves protective cases of such materials as may be at hand. The cases of the commonest British species are straight or slightly curved tubes, with a large opening at the head-end and a smaller one at the tip. The breathing organs of the larva are thread-like tracheal gills borne by the abdomen, upon the upper side of which are also a number of thin places which possibly assist in respiration by permitting diffusion of gases. The gills are kept moving, and water continually streams through the case, entering at its hinder end.

AMPHIBIOUS TWO-WINGED INSECTS (DIPTERA)

In two families of this order the early stages of existence are fully adapted to life in water, while the adults are aerial and breathe ordinary air by means of a complex set of air-tubes. These are Midges (*Chironomidæ*) and Sand-Midges (*Simuliadæ*).

Midges (*Chironomidæ*).—A very large number of Midges are included in the genus (*Chironomus*) from which this family takes its name. The eggs are laid in water, and hatch out into active wriggling larvæ, which are commonly of a red colour, and are then known as "blood-worms". This hue is caused by the presence of a pigment (*hæmoglobin*) identical with that contained in blood, and which is of great importance in breathing, since it readily takes up oxygen from the surrounding medium, easily parting with it again to the body. Some of these larvæ live at considerable depths in lakes (1000 feet in Lake Superior) or even in the sea, and the amount of red colouring-matter they possess is in direct pro-

portion to the depth at which they are able to exist, while at the same time their air-tubes are more and more feebly developed. Some of them, on the other hand, are altogether destitute of red pigment and live near the surface, being at the same time well provided with air-tubes. The larvæ may breathe entirely through the skin, but are usually provided with thread-like gills on the eleventh and twelfth rings of the body. After a time the midge-larva passes into a quiescent pupa-stage, during which breathing is effected by means of a pair of tufted gills situated at the front end of the body. These contrast markedly with the two breathing trumpets which the pupa of an ordinary gnat bears in a similar position (see p. 442), and which admit ordinary air into the breathing-tubes.

Sand-Midges (*Simuliadæ*).—These notorious blood-suckers are found in most parts of the world, sometimes occurring in vast swarms, and bestowing their unwelcome attentions on both human beings and cattle. The cylindrical larva (fig. 573) possesses a sucker at the hinder end of its body, by means of which it holds on to a stone or other firm body, and is maintained in a vertical position. Two beautiful tufted gills are borne upon the head and are kept in constant movement, which serves a double purpose, promoting respiration and also bringing a supply of food within reach of their owner. Later on the larva becomes a pupa, which is contained in a sort of open case, from which the head end freely projects. Upon this are carried two bunches of long tubular gills (fig. 573), by which breathing is carried on until the perfect insect is fully formed and ready to make its escape into the air.

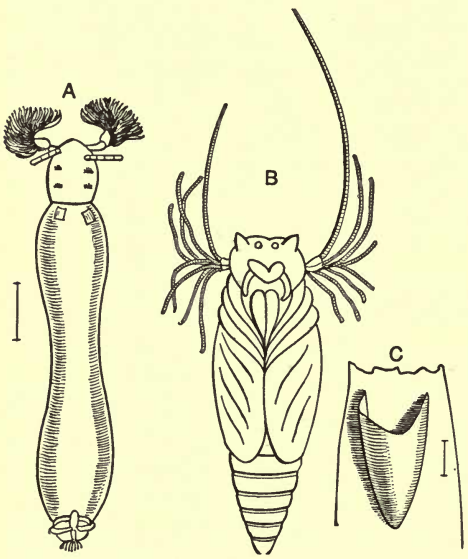


Fig. 573.—Stages in life-history of a Sand-Midge (*Simulia*), enlarged (actual size shown by short lines). A, Larva. B, Pupa. C, Pupa-case.

AMPHIBIOUS CRUSTACEANS (Crustacea)

Some mention has already been made of Land-Crabs (see p. 443) as descended from shore-dwelling forms which have lost their gills to a greater or less extent, and converted their gill-chambers into organs capable of breathing ordinary air. It would not therefore be surprising to find Crabs of truly amphibious nature forming a sort of half-way house between purely marine and purely terrestrial forms. Such a condition is actually realized by certain shore-haunting Crabs belonging to a widely-distributed family (*Grapsidæ*). The gills, though reduced in size, are still useful, and the gill-chamber possesses folds and ridges on its lining which enable it to be used as a lung. Such Crabs, when out of water, have been observed to lift up the hinder part of the body for the purpose of admitting air into the gill-chambers from the back. There is also an aperture at the front end of each chamber which is supposed to serve for the entry of water to be used by the gills.

Some account has been given in a preceding section (see p. 220) of the habits of the Robber-Crab or Palm-Thief (*Birgus*

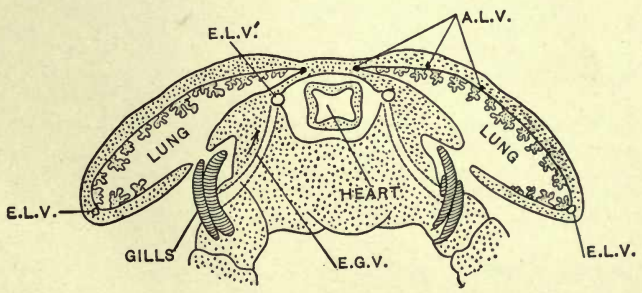


Fig. 574.—Diagrammatic Cross Section through Breathing Organs of Robber Crab (*Birgus latro*)

A.L.V., Vessels carrying impure blood to lung-folds; E.L.V., vessels bringing pure blood from lung-folds; and E.L.V'., opening of one of these into blood-space surrounding heart (pericardial space); E.G.V., vessels returning pure blood from gills to pericardial space.

latro) of the Cocos-Keeling Islands. The breathing organs of this curious creature, which is really a Hermit-Crab that has taken to live on land, are in a very interesting condition (fig. 574). The gills are much reduced in size, and the gill-chambers are divided into a small lower part for their reception, and a very much larger upper part acting as a lung, and having its lining raised into an elaborate system of folds. How far this animal is

really amphibious is rather difficult to say, for though it sometimes visits the sea, it does not of necessity follow that its gills are then used for breathing air dissolved in water, though this would seem probable. The division of each gill-chamber into two distinct parts brings to mind the arrangement found in the amphibious Apple-Snail (see p. 461).

END OF VOL. II

THE
GRESHAM PUBLISHING COMPANY

34 SOUTHAMPTON STREET, STRAND, LONDON, W.C.

* * * * * * * * *

A NEW CENTURY: A NEW ENCYCLOPEDIA

The New Popular Encyclopedia.

A LIBRARY IN ITSELF. A General Dictionary of Arts, Sciences, Literature, Biography, and History. Edited by CHARLES ANNANDALE, M.A., LL.D., Editor of Ogilvie's "Imperial Dictionary of the English Language". Profusely illustrated. In 14 handsome volumes, super-royal 8vo, in Roxburgh library binding, 12*s.* 6*d.* per volume, net.

A New Century demands a New Encyclopedia. As time advances, knowledge increases. To sum up that knowledge a new Encyclopedia is required, and everyone ought to possess that new Encyclopedia.

The Gresham Publishing Company, having acquired exclusive control of the well-known POPULAR ENCYCLOPEDIA, are now issuing **a New and Revised Edition** of that famous authoritative work of reference.

The entire work has been revised to date under the editorship of **Dr. Charles Annandale,** assisted by a staff of **Specialists** and **Encyclopedic Experts.**

The **New Popular Encyclopedia** is a worthy successor to the previous edition, which numbered among its contributors men of the high position of LORD KELVIN, SIR ANDREW C. RAMSAY, PROFESSOR J. D. EVERETT, MR. COMYNS CARR, CAPTAIN ORD-BROWN, MR. M. M. PATTISON-MUIR, &c.

In the matter of **pictorial illustration** the New Popular Encyclopedia is *alone of its kind.* In no British Encyclopedia, not even in previous editions of the POPULAR, has so extensive a use been made of the pictorial arts to assist the elucidation of the subject-matter. In addition to the large number of **plates in colour,** there are very many plates in black and white: pictures of machinery-detail, portraits, ordnance such as Vickers, Creuzot, and Krupp guns, flying-machines, ethnological types, and the hundred-and-one different objects which can be rendered clearer by the use of pictorial illustration. A complete series of **Maps** is also provided.

The **Supplements** form a very special feature of the New Popular. Besides containing many articles on general subjects they give **biographies** of living men or of men recently deceased. Thus we have MR. CHAMBERLAIN, MR. KRUGER, LORD SALISBURY, LORD ROSEBERY, MR. ARTHUR BALFOUR, MR. GEORGE WYNDHAM, LORD ROBERTS, GENERAL BULLER, MAJOR-GENERAL BADEN-POWELL (whose brother, Major Baden-Powell, secretary of the Aeronautical Society, contributes the Article on Aeronautics), &c., &c.

"THE NEW POPULAR ENCYCLOPEDIA" is a perfect library in itself, superseding, practically, the necessity of having recourse to a large number of books on different topics, and furnishing, at moderate cost, a complete body of information on all subjects.

IT IS A UNIVERSAL GAZETTEER, giving accounts of the natural and political divisions, countries, cities, rivers, lakes, &c., throughout the world.

IT IS A UNIVERSAL HISTORY, in which are to be found full general accounts of all the countries of the world, with important events and details treated at length under specific headings.

IT IS A BIOGRAPHICAL DICTIONARY—giving the lives of all important historic characters, statesmen, lawyers, literary men, scientists, inventors, engineers, artists, musicians, theologians, &c.

IT IS A COMMERCIAL DICTIONARY, explaining economic principles, treating fully the practical details of the chief industries, and giving elaborate accounts of manufacturing processes.

IT IS A DICTIONARY OF THE SCIENCES—Students of natural history, botany, geology, astronomy, chemistry, &c., will find an ample general record of modern progress in the special sciences.

IT IS A DICTIONARY OF THE FINE ARTS, explaining the technical terms, theories, and processes, and giving a historic and biographical record of the various branches of the Arts.

"THE NEW POPULAR ENCYCLOPEDIA" is, moreover, a Dictionary of the Practical Arts and Handicrafts, of Law, Medicine, Household Matters, Education, Music, Games, and Sports.

Prospectus of any Book post free.

The Household Physician.

A Family Guide to the Preservation of Health and to the Domestic Treatment of Ailments and Disease. By J. M'GREGOR-ROBERTSON, M.B. C.M. (Hon.). With an Introduction by Professor M'KENDRICK, M.D., LL.D., F.R.S., Glasgow University. Illustrated by about 400 figures in the text, and a Series of Engraved Plates. In 4 divisions, super-royal 8vo, cloth, at 9*s.* net each; also in 1 volume, Roxburgh binding, £1, 13*s.* net; 2 volumes, ditto, £1, 17*s.* net.

One aim of this book is to supply in as plain language as can be used some knowledge of what science has to say as to the body which we inhabit; the second aim is to give reliable assistance in the domestic treatment of simple ailments. The bodily ills to which young and old are liable are considered more fully than is usual in popular works.

The first portion of the book treats of the human body in health, and the various changes produced by disease. This part has been divided into sections, each section being devoted to one set of organs. For example, the bones and joints are considered in one section, the nervous system in another, the digestive organs in a third, and so on. The first half of each section describes the particular organs in their healthy condition, and the second half discusses the diseases to which they are liable. By this method the healthy and diseased states of each part of the body are placed in relationship to, and mutually explain, one another. This section, moreover, contains special chapters on the MANAGEMENT OF CHILDREN IN HEALTH, the DISEASES OF CHILDHOOD, and the DISEASES OF WOMEN.

The second portion of the book is devoted to HYGIENE, or the conditions of health as regards FOOD, DRINK, CLOTHING, EXERCISE, &c., and the rules to be observed for the promotion of health, both of individuals and communities. Details are given of the requirements of a HEALTHY HOUSE, in its construction, ventilation, water-supply, drainage, &c.

In the third portion of the work the nature and mode of ACTION OF DRUGS and other remedial agents are explained. But this part includes more than mere drugs. ELECTRICITY, an agent as valuable in medicine as it is in commerce, and MASSAGE, or medical rubbing, another new and formidable antagonist to ill-health, will also be fully treated.

In the remaining portion of the book the methods of dealing with ACCIDENTS AND EMERGENCIES find a place, and the commoner SURGICAL INSTRUMENTS are described and their mode of use explained; SICK-NURSING receives attention, and recipes for INVALID COOKERY and Notes of MEDICAL PRESCRIPTIONS are given.

The ILLUSTRATIONS are very numerous, consisting of about four hundred figures printed in the text, and a series of thirty-one engraved plates, many of which are in colours.

A GREAT HISTORICAL WORK.

A History of the Scottish People.

From the Earliest to the Latest Times. By Rev. THOMAS THOMSON and CHARLES ANNANDALE, M.A., LL.D. With 40 Original Designs by W. H. MARGETSON, ALFRED PEARSE, WALTER PAGET, GORDON BROWNE, and other eminent artists. In 6 divisional volumes, super-royal 8vo, cloth elegant, 8*s.* 6*d.* net each.

The main features may be stated as follows:

It is a full and detailed History of Scotland from the Earliest Times to the Latest.

It is a History of the Scottish People, their manners, customs, and modes of living at the various successive periods.

It is a History of Religion and Ecclesiastical Affairs in Scotland.

It is a History of Scotland's progress in Commerce, Industry, Arts, Science, and Literature.

It is illustrated by a series of original designs reproduced in facsimile from drawings by eminent artists.

Prospectus of any Book post free.

NEW EDITION, REVISED AND GREATLY AUGMENTED.

Ogilvie's Imperial Dictionary

OF THE ENGLISH LANGUAGE. A complete Encyclopedic Lexicon, Literary, Etymological, Scientific, Technological, and Pronouncing. Edited by CHARLES ANNANDALE, M.A., LL.D. Illustrated by above three thousand engravings on wood, besides a splendid series of full-page plates, many of which are coloured. This edition of the IMPERIAL DICTIONARY is beautifully printed on paper of imperial size, specially made for the Work. It is issued in eight Divisional Volumes of a handy size for reference, bound in cloth, with a fine design on side, at 10*s.* net each volume.

The reception accorded by the press and the public to this new edition of the IMPERIAL DICTIONARY has been such as to show that the care and labour bestowed upon it have met with due recognition, and to prove that it will continue fully to maintain its established position as a standard lexicon of the English language, and as a work of the highest utility for the purposes of general reference and everyday requirement.

DISTINCTIVE POINTS.

To sum up the chief points of this edition—

I. It is the latest revised dictionary, and has a supplement of many thousand new words.

II. It contains more words, exclusive of compound and obsolete words, than any other English dictionary.

III. The pronunciation is explained on a plan which is simplicity itself.

IV. It gives the pronunciation and the meaning of the word as recognized *to-day*.

V. It has more illustrations than any other English dictionary.

VI. It has full-page plates (coloured and otherwise), which are an outstanding feature of the work. No other English dictionary contains full-page plates.

VII. It has clear type, beautifully printed on fine paper, and is substantially and elegantly bound.

VIII. It has a specially prepared Supplement issued with *each* volume, and not, as is usually the case, relegated to the end of the complete work.

IX. It has a very full Appendix, probably the best and finest given with any dictionary in the world.

X. It is sold on a plan at once acceptable and convenient, within the reach of all, and the price is very moderate.

"The IMPERIAL DICTIONARY", says the *St. James' Gazette*, "is a work which fairly deserves the epithet of monumental. It is really what it professes to be—'a complete encyclopædic lexicon, literary, scientific, and technological'. In other words, it is the best dictionary of its kind in the English language, and its kind is the best."

"We have no hesitation in saying", writes the *Spectator*, "that it will prove a most thorough piece of workmanship, and that among reference-books of its class it will hold the first place, both as an authority and a source of instruction and entertainment."

"The encyclopedic method of treatment which has been adopted", remarks the *Athenæum*, "will be found of the greatest service, affording as it does to the reader the advantages of the ordinary dictionary combined with those of the encyclopedia."

The *St. James' Gazette* says:—"The encyclopædic part is executed with great skill and accuracy; and the genius of the editor has been exercised with the power and precision of a hydraulic press upon the enormous masses of facts with which he has had to deal".

Prospectus of any Book post free.

The Cabinet of Irish Literature:

SELECTIONS FROM THE WORKS OF THE CHIEF POETS, ORATORS, AND PROSE WRITERS OF IRELAND. Edited by CHARLES A. READ, F.R.H.S., and KATHARINE TYNAN HINKSON. In 4 volumes, super-royal 8vo, cloth extra, gilt edges, price 8*s.* 6*d.* net each.

Coulson Kernahan

As there is an Irish Nationality, so there is an Irish Literature, in which that Nationality has found expression. And what a magnificent Literature it is! how brilliant the roll of Irish writers from Swift, Steele, and Goldsmith, to Sheridan, Grattan, Moore, and the score of gifted men and women who are identified with the present renaissance of Irish letters!

THE CABINET OF IRISH LITERATURE is an attempt to give every Irishman, every Irish household, a share in the priceless treasures with which the literary genius of the race has enriched mankind.

It brings within the compass of a single great work a representative selection of all that is best in Irish Literature. Not, be it said, the old Irish Literature in the old Irish tongue; of that most is unknown to the people itself, though a good deal of it, in translation, will be found in this book. By Irish Literature is meant the Literature read and understood by the Irishmen of the present day—the expression of the ideas they really feel, of the life they truly live, in Mayo, in Limerick, in Cork, and in Derry.

It is a selection made without fear or favour, free from any bias, religious, political, or social. Merit is the only passport to its pages.

It gives, in brief pointed biographical notices, the life-history of every great Irish writer. We are enabled to realize the personality of the man as well as appreciate the qualities of his work.

It deals not only with the past but with the present; and it is the only work that brings home to us by illustrative extracts the great revival in Irish Literature that is now taking place. W. B. Yeats, Douglas Hyde, George Bernard Shaw, Nora Hopper, Seumas MacManus, Richard Ashe King, George Egerton, Moira O'Neill, are a few among the many scores of modern writers whose works are represented in the CABINET.

No Irishman who is proud of his nationality can afford to be without a work which thus focuses the whole intellectual activity of the race. To the younger generation it will be an inexhaustible source of inspiration, a priceless influence in forming their taste, in moulding their character—in a word, in perpetuating those qualities which now, as in the past, are associated with the name of Irishman.

The CABINET was originally planned by Mr. Charles Anderson Read, but this accomplished Irish poet and novelist did not live to see the fruition of his hopes. His work was completed by Mr. T. P. O'Connor, under whose auspices the first edition was issued. Now, after the lapse of nearly a quarter of a century, the time has come for a new edition of this monumental work, which shall take due account of the extraordinary activity in Irish letters during the intervening years. Under the able editorship of Miss Katharine Tynan (Mrs. Katharine Tynan Hinkson), herself one of Ireland's most distinguished writers, the work has been thoroughly revised and brought down to the present hour.

In its get-up it is all that a book of its great importance should be. The illustrations are many and of the highest artistic value. Some of the most eminent black-and-white artists of the day, including John H. Bacon, Charles M. Sheldon, W. Rainey, R.I., G. P. Jacomb-Hood, R.I., and W. H. Margetson, have been commissioned to illustrate typical scenes from the masterpieces of our literature, and these drawings, rendered by the latest processes of photographic reproduction, and printed on specially prepared paper, add an unique charm to the work. The CABINET is further embellished with a large number of photographs of the most eminent Irish writers; and the cover design, in gold upon green cloth, is the work of Talwin Morris, the well-known designer.

F. Frankfort Moore

Prospectus of any Book post free.

The Book of the Home.

AN ENCYCLOPÆDIA OF ALL MATTERS RELATING TO THE HOUSE AND HOUSEHOLD MANAGEMENT. Produced under the general editorship of H. C. DAVIDSON, assisted by over one hundred specialists. Copiously illustrated by coloured and black-and-white plates and engravings in the text. In 4 volumes, super-royal 8vo, cloth, with artistic design, price £2, 2*s*. net. Also in 8 divisional volumes, cloth, price 5*s*. net each.

THE BOOK OF THE HOME is intended to form a complete work of reference on all subjects connected with household management. No efforts have been spared to ensure that every matter bearing upon the Home and Home Life shall receive full and sufficient treatment, and that the information given shall be reliable and in the best sense of the phrase up-to-date.

A few among over one hundred specialists who have contributed to the work:

Mrs. ADA S. BALLIN, Editor of *Baby—the Mother's Magazine*, and of *Womanhood*.

Miss BERTHA BANNER, Training Teacher of Sewing and Dressmaking at the Liverpool Technical College for Women.

Mr. A. BLACK, C.E., Architect, Author of *First Principles of Building*.

Mrs. DAVIDSON, Author of *Dainties*, *What our Daughters can do for themselves*, &c.

Miss J. FORSTER, Principal of the Cheshire County Council Dairy Institute.

Mrs. H. R. HAWEIS (the late), Author of *The Art of Decoration*, *The Art of Beauty*, &c.

Miss HELENA HEAD, Principal of the Liverpool Girls' School for Secondary Education in Domestic Science, and Author of the *Manual of Housewifery*.

Mrs. A. HODGSON, Home Decorator to *The Lady*.

Mr. R. KEITH JOHNSTON, Author of *Household Difficulties and How to overcome Them*.

Miss GERTRUDE J. KING, Secretary to the Society for Promoting the Employment of Women.

Miss E. E. MANN, Head Teacher at the Liverpool Training School of Cookery.

Colonel M. MOORE-LANE, Contributor to the *Field* and other agricultural papers.

Mrs. C. S. PEEL, Dress and Household Editor of *Hearth and Home*, and Author of *The New Home*.

Miss. B. SIBTHORPE POOLEY, Lecturer to the Liverpool Ladies' Sanitary Association.

Miss RANKIN, Head Teacher of Laundry Work at the Liverpool Technical College for Women.

Miss FLORENCE STACPOOLE, Lecturer to the National Health Society and the Councils of Technical Education, and Author of *Handbook of Housekeeping for Small Incomes*, &c.

Mr. DAVID TOLLEMACHE, late editor of *The Chef and Connoisseur*.

The contents of THE BOOK OF THE HOME may be grouped under four heads. The first deals with all matters concerning the House—from the choice of its site to the least of its internal decorations. The householder is instructed in the laws regarding landlord and tenant, and counselled in the important matters of sanitation and ventilation, heating and lighting, and the stocking and management of the garden. The housekeeper is advised as to furnishing, everything necessary for the comfort and adornment of a well-equipped house being described in detail, hints being also given regarding removals, painting and papering, artistic decoration, arrangement of linen and store cupboards, &c.

In the second the daily routine of the Household is considered—the duties of the servants, their wages, their leisure and pleasures, the management of the kitchen, laundry, and store-room. Plain and fancy cooking receive due attention, recipes being given of a large variety of dishes, and suggestions made for breakfast, lunch, afternoon-tea, dinner, and supper. A number of menus are added suitable for the different seasons. Invalid cookery also has its special section.

In the third are discussed the legal and customary duties, and the occupations and pastimes, of Master and Mistress, the former being instructed as regards insurance and the making of a will, and the smaller matters of carving, the care of the wine-cellar, and the inspection of garden and stables, while the latter is advised as to account-keeping, payments, shopping, and innumerable other matters connected with her duties as Mistress. Other subjects treated under this head are dress, home occupations, visiting and entertaining, and indoor and outdoor amusements.

In the fourth sound, systematic, and practical advice is given as to the management, in health and sickness, and the education, of children, and also on such important subjects as occupations for boys and girls, the ceremonies necessary on the coming out of a daughter, and the preparations and formalities necessary before and after a marriage.

THE BOOK OF THE HOME will thus be at once an indispensable ally to the young bride and the novice in housekeeping, and a valuable work of reference to the more experienced.

Prospectus of any Book post free.

The Natural History of Animals:

The Animal Life of the World in its various Aspects and Relations. By J. R. AINSWORTH DAVIS, M.A., of Trinity College, Cambridge, and of University College, Aberystwyth. Profusely illustrated with full-page colour and black-and-white plates, and engravings in the text, by eminent animal artists. In 8 half-volumes, cloth extra, price 7*s.* net each.

While the sum of human knowledge is gigantic now as compared with what it was a hundred years ago, in the department of Natural History the books upon which the great majority of us must depend have undergone practically no change. The general Natural History still follows the lines adopted by Goldsmith in his famous and delightful *Earth and Animated Nature*. That is to say, they are little more than classified catalogues of animals, taking up in succession the various groups and individuals, and describing them one after another, each as standing by itself. This is not what the intelligent reader of the present day requires. He must be put in a position to take a comprehensive grasp of the subject; he demands a competent guide, not a directory, however accurate.

It is with this end in view that THE NATURAL HISTORY OF ANIMALS has been compiled. It treats this great subject on essentially modern lines, giving an accurate and vivid account of the habits, relationships, mutual interdependence, adaptation to environment, &c., of the living animals of the world.

It is needless to say that the production of such a work demanded a man who has devoted his life to the study of biology and zoology, and who at the same time is a gifted writer and expounder. This rare combination has been found in the person of Prof. J. R. AINSWORTH DAVIS, M.A., of Trinity College, Cambridge, and of University College, Aberystwyth, the author of the present work. Prof. DAVIS is well known to naturalists as an ardent worker in Natural History, particularly in the field of marine zoology. He is a very distinguished graduate of Trinity College, Cambridge, the chief scientific school in Britain, perhaps in the world, and has done a great deal of literary work, both scientific and in other directions.

Briefly, **the object of Prof. Davis's work** is to give in a readable form and in non-technical language a general survey of the whole animal world from the stand-point of modern science—and the work may fairly claim to be a **Natural History on a new plan**, the first comprehensive work in English of its own special kind. Formerly Natural History had much the character of a miscellaneous aggregate of disconnected facts, but hardly any fact or feature connected with any animal can now be considered as isolated from others; and animals as a whole must be looked upon as interrelated in the most surprising manner both with one another and with their surroundings.

Every household library should contain a Bible, a Dictionary, an Encyclopedia, and a work on Natural History. This is the "irreducible minimum"; other books we may have, these we must. For THE NATURAL HISTORY OF ANIMALS it may fairly be claimed that it has a better title than any other work to become the **Natural History for the Household**. It is a work in which the adult reader will find a never-failing mine of information, while the younger members of the family will delight in its wealth of illustration, and its store of interesting and suggestive anecdote.

To teachers THE NATURAL HISTORY OF ANIMALS may be regarded as indispensable. More than usual attention has of late been directed to the important subject of **Nature-study**; and in this respect the appearance of Prof. Davis's work could scarcely have been more fitly timed. In the domain of Natural History it is pre-eminently the book for the purpose. Its clear and orderly arrangement of facts, its masterly grasp of general principles, its comprehensiveness of scope and simplicity of style, combined with the most absolute scientific accuracy, render this work an invaluable book of reference for those who aspire to teach Nature-study on up-to-date principles.

The Illustrations, as befits a work of such importance, are on the most lavish scale. A large number are in colour, reproductions, by the latest processes of colour engraving, of exquisite pictures by the most eminent animal draughtsmen. In illustrating the work talent has been sought wherever it was to be found; and the list of artists is representative of several nationalities. A large number of the designs are the work of Mr. A. FAIRFAX MUCKLEY, who is probably unsurpassed in the capacity to depict living creatures with absolute fidelity to detail without sacrificing the general artistic effect. FRIEDRICH SPECHT, one of the most eminent German animal painters of the past century, is represented in THE NATURAL HISTORY OF ANIMALS by many of his best designs in colour and black-and-white. W. KUHNERT, another German artist whose work is universally admired; and M. A. KOEKKOEK, the talented Dutch painter, are also among those who have assisted in the embellishment of the work. An important feature is the series of diagrammatic designs showing the structure of certain typical animals, specially drawn under the direction of Prof. Davis.

Prospectus of any Book post free.

The Modern Carpenter, Joiner, and Cabinet-Maker:

A Complete Guide to Current Practice. Prepared under the editorship of G. LISTER SUTCLIFFE, Architect, Associate of the Royal Institute of British Architects, Member of the Sanitary Institute, editor and joint-author of "Modern House-Construction", author of "Concrete: Its Nature and Uses", &c. With contributions from many specialists. Illustrated by a series of about 100 separately-printed plates and 1000 figures in the text. In 8 divisional volumes, super-royal quarto, handsomely bound in cloth, with cover design by Mr. TALWIN MORRIS, price 7*s.* 6*d.* net each. In complete sets only.

In preparing THE MODERN CARPENTER the editor has had the great advantage of working upon the basis of Newlands's *Carpenter and Joiner's Assistant*, which for nearly half a century has been accepted as a **standard authority** on the subjects of which it treats, and for many years has been recommended by the Royal Institute of British Architects as **a text-book** for the examination of that society. And yet in the present work it has been possible to preserve only a very small part of Newlands's treatise, invaluable though this has been to two generations of craftsmen. While the fundamental features of arrangement and method which distinguish this famous work have been retained, the matter has had to be **entirely rewritten,** and many new sections have been added, on subjects not touched upon in the older work, with which the carpenter of the present day requires to be familiar.

In the new book, indeed, the old foundations that have stood the test of half a century of practical use have been retained, but **the superstructure is wholly new.**

The lesson to be learned from this fact is not far to seek. It is that the modern carpenter requires a **far wider expert knowledge** than sufficed his predecessor. The development of wood-working machinery, the introduction of new kinds of timber, improvements in the design of structures, the more thorough testing of timbers, and progress in the various industries with which Carpentry, Joinery, and Cabinet-making are intimately allied, have all helped to render the craft more complex. The carpenter of the present day has no use for the old "rule of thumb" methods; his calling is both an art and a science, and **knowledge, knowledge, and again knowledge** is the primary condition of success.

The editor of THE MODERN CARPENTER, **Mr. G. Lister Sutcliffe,** Associate of the Royal Institute of Architects, **needs no introduction** to practical men; his name is already well known not only through his professional position in the architectural world, but through his editorship of *Modern House-Construction*, a work which, although issued only a few years ago, has already become a standard book of reference. Mr. SUTCLIFFE'S large experience has enabled him to enlist the services of a **highly-qualified staff of experts,** whose special knowledge, acquired through long years of practical work, is now placed at the disposal of every member of the craft. The first condition in selecting the contributors to the work was that they should be **practical men,** not only possessing the indispensable knowledge, but having the ability to impart it. The result is that within the eight divisional-volumes of this work we have a treatise on every branch of the craft, distinguished by four outstanding qualities:—It is (1) **complete,** (2) **clear,** (3) **practical,** and (4) **up-to-date.**

An idea of the scope of THE MODERN CARPENTER may be gathered from the fact that while its predecessor, *The Carpenter and Joiner's Assistant*, comprised only **eight** sections, the new work includes no fewer than **sixteen.** A glance at these will show that the work **covers the whole field**; it is a complete encyclopædia upon every subject that bears upon the everyday work of the practical man.

I. Styles of Architecture.
II. Woods: Their Characteristics and Uses.
III. Wood-working Tools and Machinery.
IV. Drawing and Drawing Instruments.
V. Practical Geometry.
VI. Strength of Timber and Timber Framing.
VII. Carpentry.
VIII. Joinery and Ironmongery.
IX. Staircases and Handrailing.
X. Air-tight Case-Making.
XI. Cabinet-Making.
XII. Wood-Carving.
XIII. Shop Management.
XIV. Estimating.
XV. Building Law.
XVI. Index, Glossary, &c.

The Illustrations are not the least of the many notable features of this great undertaking. The work is embellished in the first place with about **100 full-page plates,** reproduced, some in colours, by the most approved processes of mechanical engraving, and printed on specially-prepared paper. In addition to this unique collection there are no fewer than **1000 diagrams and designs** in the body of the work. No trouble or expense has indeed been spared to procure illustrations where these could elucidate the text.

Prospectus of any Book post free.

Charles Dickens' Novels.

The Imperial Edition of the Novels of CHARLES DICKENS, in 15 volumes, large square 8vo, cloth extra, gilt top, price 4*s.* 6*d.* net each volume.

An Ideal Issue. ONE NOVEL, ONE VOLUME. Despite varying lengths, the paper, &c., is so adjusted that each volume is uniform in thickness and size.

The Cheapest Edition. The price of each volume is 4*s.* 6*d.* net, making the edition the *cheapest of the best editions.*

Sumptuously Bound. The cloth is of the finest and is imperial red in colour. The embellishments (produced in gold) are an appropriate design of national arms and imperial emblems by the eminent designer, Talwin Morris.

Illustrations a Unique Feature. Every picture drawn specially at enormous cost for this "Imperial" edition by the best known and most celebrated Artists of *to-day.*

George Gissing's Masterly Study. A literary character study, the work of this great authority, forms one of the volumes of this issue, and is illustrated with pictures of some of the quaint old hostelries and places made famous by Dickens, and is altogether an invaluable addition to this issue.

Presentation Portrait. To every subscriber to this edition will be presented with the last volume a magnificent Photogravure of Charles Dickens. It is printed on the finest plate paper, 22 inches by 30 inches, and has been specially engraved for this edition.

A List of the Novels.

The following is a list of the volumes in the Imperial Edition:—

1. The Pickwick Papers.
2. Oliver Twist.
3. Nicholas Nickleby.
4. Martin Chuzzlewit.
5. The Old Curiosity Shop
6. Barnaby Rudge.
7. David Copperfield.
8. Bleak House.
9. Sketches by Boz.
10. Hard Times and Master Humphrey's Clock.
11. Christmas Books.
12. Dombey and Son.
13. Little Dorrit.
14. A Tale of Two Cities.
15. Charles Dickens: A Critical Study. By GEORGE GISSING.

Prospectus of any Book post free.

301521

Davis

QL43
D3
v.4

BIOLOGY
LIBRARY
G

UNIVERSITY OF CALIFORNIA LIBRARY